OF
72-13

GEOLOGY, HYDROLOGY, THICKNESS AND QUALITY OF SALT AT THREE ALTERNATE SITES FOR DISPOSAL OF RADIOACTIVE WASTE IN KANSAS

Edited by

Charles K. Bayne and Dwight Brinkley

Compiled by consultants of AEC and the staff of and consultants to the State Geological Survey of Kansas, The University of Kansas, Lawrence, Kansas under the direction of Charles K. Bayne, Ernest E. Angino, and William W. Hambleton.

This report was prepared by the State Geological Survey of Kansas and The University of Kansas Center for Research, Inc., Lawrence, Kansas for the U.S. Atomic Energy Commission, Union Carbide Corporation under AEC/UC Subcontract No. 3484.

September 1972

CONTENTS

PLATES

FIGURES

TABLES

Chapter 1

INTRODUCTION

by

Charles K. Bayne

In March, 1972, three sites were selected by the AEC for additional study for the disposal of radioactive wastes in Kansas. Site A (AEC 3) is located in south-central Lincoln County, site A-1 (AEC 4) is located in north-western Lincoln County and site D-2 (AEC 5) is located in south-central Wichita County (Fig. 1). These sites are located in areas studied by Angino and others (1972).

Field work was started on this study on April, 1972, and continued until June 23, 1972. During the study, the surface geology, hydrology and cultural features were mapped and studied in each area by Charles K. Bayne and Dwight Brinkley (Chapter 2, this report).

A test hole was drilled on or adjacent to each of the three areas and the salt section was cored. The cores were studied and interpreted by Edwin D. Goebel and Louis F. Dellwig, consultants, and the results of their studies are reported in chapters 4 and 5, respectively, of this report.

Hydrologic testing of rocks above and below the salt and in the Cretaceous rocks was performed by personnel of the U.S. Geological Survey, AEC Hydrology Projects Office, Denver, Colorado.

[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]

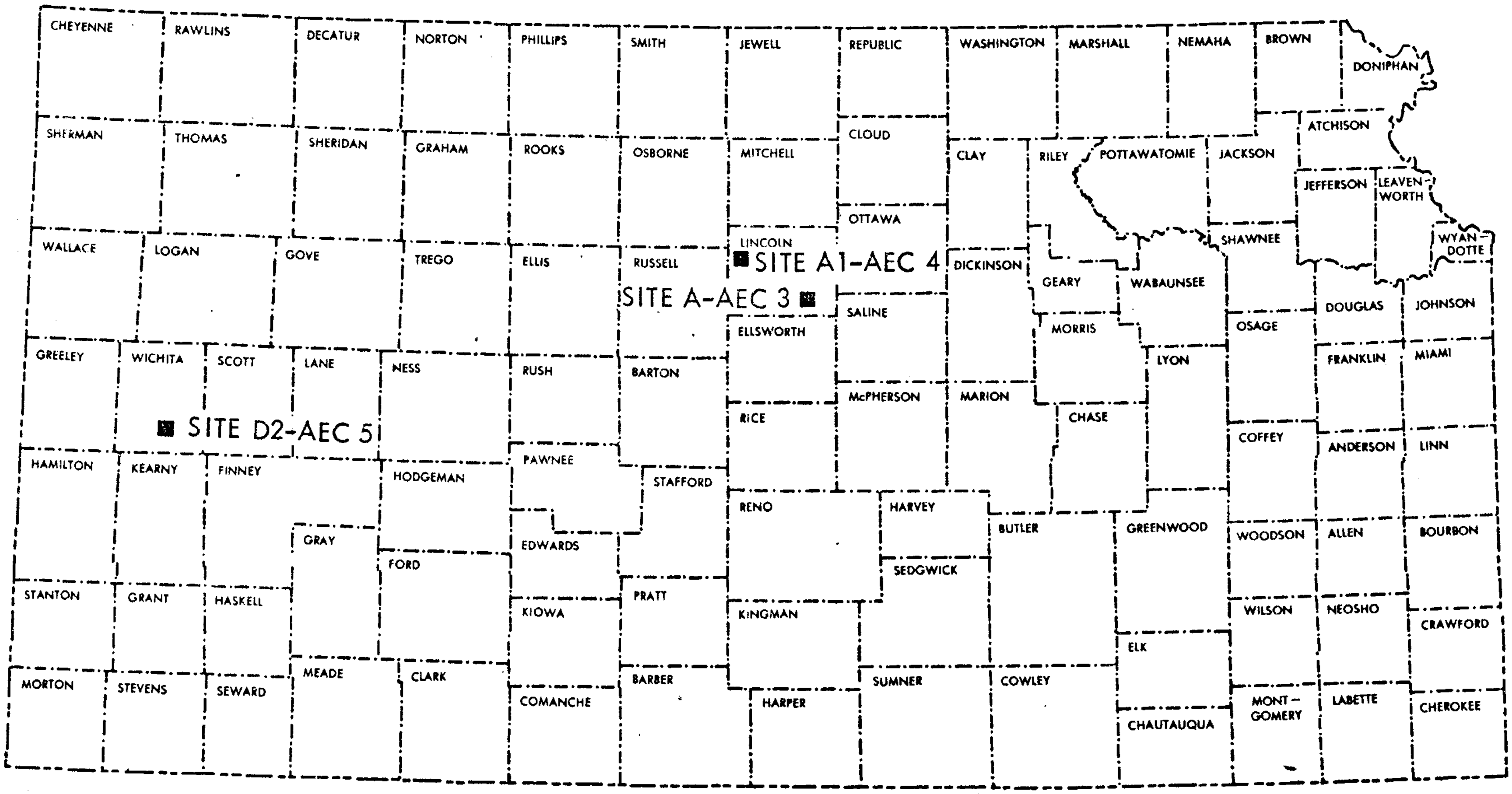


Figure 1.--Index Map of Kansas Showing Location of Sites A, A1, and D2.

During the hydraulic tests on the test holes, water samples were collected from the principal water-bearing zones. The results of the analyses on the water samples, interpreted by E. E. Angino, are given in Chapter 3 of this report.

G. W. James made insoluble residue and x-ray diffraction analyses of selected core samples from AEC 5. The results of these analyses are included in this report in Chapter 6.

Some of the data used in compilation of this report are from sources over which the Geological Survey has no control and the reliability of this information is in no way assured or guaranteed by the Geological Survey.

The State Geological Survey of Kansas is charged with the responsibility for continuing studies on the geologic effects of storing highly radioactive materials in subterranean areas. At the present time, the State Geological Survey of Kansas neither endorses or opposes the concept of storing of radioactive material in salt, nor any other disposal concept. As our primary charge is to the State of Kansas and the people of Kansas, it is our prime concern that before we endorse the concept of storing highly radioactive wastes in salt, it must be demonstrated that all aspects of geologic safety related to the project have been satisfactorily considered. It is upon this premise that any report prepared by the State Geological Survey is based and upon which any future report will be based.

ACKNOWLEDGEMENTS

Many people contributed to the compilation of this report. We would like to thank as a group those people who gave of their time and knowledge. Special thanks is due Robert F. Walters, Robert Dilts, Sharon Hagan, Renate Hensiek, Karen Mumford, and Charles Barksdale.

Chapter 2

GEOLOGY, HYDROLOGY, AND CULTURAL FEATURES

by

Charles K. Bayne and Dwight Brinkley

Area A (AEC 3)

Location

Area A is located in south-central Lincoln County, Kansas, and includes the SE 1/4 Sec. 21, S 1/2 Sec. 22, all of Sec. 27 and the E 1/2 Sec. 28, T. 13S., R. 8W. AEC test hole 3 was drilled in the center of a 300 foot square tract in the NE cor. SE 1/4 Sec. 22, T. 13S., R. 8W. All culture features such as houses, water wells, power lines, pipelines and buried communication cables were located by means of an odometer and plotted on topographic maps. Information on water supplies was obtained principally through interviews with the local residents; however, field measurements were made in most of the wells in the 1440- acre site and in a few of the wells within a 2-mile radius of the border of the 1440-acre site. All the wells within a 2-mile and 5-mile radius of the site were located, but on only a few wells were hydrologic data obtained.

Drainage

Most of the area within a 5-mile radius of the site is drained by tributaries of the Saline River. The drainage divide is located near the periphery of the 5-mile radius in the southern part of the area (Fig. 2). South of the divide drainage is to the Smoky Hill River. Spring Creek west of the site and Elkhorn Creek east of the site generally maintain a small flow throughout the year but may cease to flow during prolonged drought periods.

Geology and Topography

The topography consists of relatively flat-topped hills with steep walls breaking downward to relatively narrow valleys. Maximum relief is about 250 feet. In the 1440-acre site area the hill tops are underlain by thin deposits of Carlile Shale. These deposits have a maximum thickness of about 20 feet. The escarpment near the edge of the hill tops is held up by the Greenhorn limestone (Cretaceous Age) which is about 65 feet thick. The Greenhorn extends well down the hill slopes. The Graneros Shale underlies the Greenhorn and is about 30 feet thick. This unit generally occupies the lower part of the slope. The Carlile Shale, Greenhorn Limestone and Graneros Shale are mapped as a unit on Figure 2. The Dakota Formation is locally present in the lowest part of the hill slopes and underlies thin colluvial or alluvial deposits in the valley bottoms.

Cultural Features

No home sites are located in Area A. All of the land in Area A is used for grazing except about 120 acres in the western part of this area.

High-pressure natural gas pipelines traverse this part of Lincoln County. Two parallel pipelines owned by the Cities Service Company are adjacent to the east side, and in part, in the 1440-acre site in Area A (Fig. 2). These pipelines run in a north-south direction; the west line is an 8-inch pipeline and the east line is a 12-inch pipeline. There are no service connections to these lines within a 5-mile radius of the site. About 1/2 mile outside the northwestern part of the 5-mile radius are four high-pressure, natural gas lines owned by the Pipeline Company of America and running in a northeast-southwest direction. One line is 24 inches in diameter, one 26 inches and two are 36 inches in diameter. No service connections are within the area.

A buried communications cable trending north-south crosses the area about 1 mile east of the 1440-acre site. This cable connects with an east-west trending cable which is about 1 mile south of the 1440-acre site at its nearest point (Fig. 2). These cables are operated by the Bell System. Another buried cable runs in an east-west direction about 3 1/2 miles south of the 1440-acre site. This cable is operated by the United States Air Force (Fig. 2). Local service is furnished residents in the area by above-ground lines. These service lines are not shown in Figure 2.

Electric power is supplied to the local residents by the Sunflower Electric Cooperative. Most lines serving the area are single-phase 7200-volt lines (Fig. 2). A 3-phase, 7200-volt line enters the 5-mile radius area from the south and runs west along the section line 3 miles south of the 1440-acre site. A main power-transmission line crosses the area in a northwest-southeast direction about 2 miles south of the 1440-acre site. This line, owned by the Central Kansas Power Company, is designed for 230,000 volts but is presently energized at 115,000 volts.

Water Supply

Area A is generally well supplied with domestic and stock water supplies. The Dakota Formation is the principal aquifer in the area; however, a few wells obtain water from alluvium or colluvium in the stream valleys. Depths of wells are quite variable over the area depending on the topographic location of the well. A few wells are located on the tops of the hills; more generally they are located on the slopes or in the valleys. Depths of wells in the area range from about 30 feet in some valley areas to more than 300 feet in upland areas where the Dakota Formation is penetrated.

The potential yields of wells in the area are difficult to estimate. Stock and domestic wells generally are not fully penetrating, and are only deep enough to furnish the required quantity of water. Records of only three wells that produce appreciable quantities of water in this area were obtained during this study. A well located just south of Interstate Highway 70 near the east 5-mile radius of Area A produced 195 gallons per minute (gpm) and another well located adjacent to I-70 about 3 miles west of the 5-mile radius produced about 100 gpm. A third well located about 3 miles south of the city of Lincoln produces about 250 gpm. All these wells obtain water from Lower Cretaceous rocks. Hydrologic testing on AEC test hole 3 indicated that this well may produce as much as 300 gpm from the Lower Cretaceous rocks.

Hydraulic Testing

Three zones were tested for their hydrologic characteristics in AEC 3. The first test was a recovery test in which the packer was set at 967 feet and the zone between 967 and 1100 feet was tested. Water was swabbed from the tubing to a point below the static head and allowed to recover for 48 hours. Water recovery was very slow during the test, indicating a very low permeability.

In the second test on AEC 3 the packer was set at 406 feet and the zone between 406 feet and 1100 feet was tested in the same manner. Water recovery was very slow during the test, indicating the lower permeability of the tested zone.

The Lower Cretaceous rocks in AEC 3 were tested by pumping the well. A plug was set in the bottom of the 8 5/8 inch casing and the casing was perforated opposite the sandstones. The well was pumped at a rate of 51 gpm for 12 hours with 7 feet of drawdown. Static water level was 130 feet below the land surface. A properly constructed well at this location probably would produce in excess of 300 gpm from the Lower Cretaceous rocks.

Samples of water collected during the testing of the zone between 967 and 1100 feet were not definitive of the formation water. The formation could not be properly sampled because of the low permeability of the rocks in this zone. The sample collected from the zone between 406 and 1100 feet probably contained some drilling-water residue. Samples collected from the Lower Cretaceous rocks are probably representative of the formation water when the entire Cretaceous section is sampled. Better quality water can usually be obtained from the upper part of the Dakota Formation.

Area A-1 (AEC 4)

Location

Area A-1 is located in northwestern Lincoln County and includes all of sections 8 and 17, T. 11S., R. 10W. AEC test hole 4 was drilled in the center of a 300 foot square in the SW cor. Sec. 9, T. 11S., R. 10W. adjacent to sections 8 and 17 (Fig. 3). Data on cultural features and information on water supplies were collected in the same manner as in Area A.

Drainage

Area A-1 is drained by tributaries to the Saline River. Most of the streams within the two square mile area are not perennial streams; however Spillman Creek, which drains much of the northeast part of the area within the 5-mile radius, flows except during prolonged drought periods. Wolf Creek on the south maintains some flow all the time.

Geology and Topography

Area A-1 topographically is a flat to rolling, high upland, and is underlain by thin loess deposits overlying the Upper Cretaceous Carlile Shale, except in the SW cor. of section 17 where the upper part of the Greenhorn Limestone crops out in the valley of a small stream. The oldest exposed rocks, the Graneros Shale and the Dakota Formation, crop out about two miles south of the southern part of the two square mile area. In Area A-1 about 30 feet of Carlile is present. The Greenhorn is about 90 feet thick and is underlain by 40 to 50 feet of Graneros Shale. The combined thickness of the Dakota and Kiowa formations is about 420 feet. Alluvial deposits occur in Spillman Creek valley and in Wolf Creek valley.

Cultural Features

Two modern farmsteads are located in Area A-1. Most of the land is under cultivation in this area.

One 12-inch, crude-oil pipeline, owned by the Amoco Pipeline Company, traverses in a west-northwesterly to east-southeasterly direction about 1 1/2 miles north of the 2 square mile area (Fig. 3).

No buried communication cables were observed within a 5-mile radius of Area A-1 except service cables extending from the overhead lines to the service outlet.

Electric power in Area A-1 south of T. 10S. is furnished by single-phase, 7200-volt lines owned by the Sunflower Electric Cooperative (Fig. 3). North of this area, power is furnished by the Mankato-Jewell Electric Cooperative. The nearest 3-phase service is at either Lucas or Sylvan Grove.

Water Supply

Area A-1 is generally adequately supplied with water from the Dakota Formation. Alluvium in the valleys of Wolf Creek and Spillman Creek yield moderate supplies of water to wells within a 5-mile radius of the 2 square mile area. The quantity of water available from many of the wells in the alluvium is sufficient only for stock or domestic supplies. One well in the Spillman Creek valley is reported to have an initial yield of about 300 gpm, but the saturated thickness of the alluvial deposits at this site is thin and this well probably would yield no more than 100 gpm if pumped continuously. Surface water in the principal streams is generally high in chlorides at low flow stages. Alluvial deposits also probably contain high chloride water locally.

Most wells within a 5-mile radius of site A-1 obtain water from the Dakota Formation. No large-capacity wells are within this area, and tests on the Dakota aquifer in AEC 4 indicate that a maximum yield of about 250 gpm could be obtained. However, with sustained pumping a yield of about 150 gpm might be expected.

In Lincoln County water from the Dakota is locally of poor quality. This water is of a sodium bicarbonate type and may be high in chloride and sulfate ions. Within a 5-mile radius of the site, much of the water is high in sodium bicarbonate. Chlorides and sulfates are generally low in the southern part of the area but increase in concentration toward the north and west. The water may be unusable in the northern and western parts of this area. Samples of water from AEC 4 were contaminated with drilling fluid and were not definitive of the formation water.

Hydraulic Testing

Three zones were tested for their hydrologic characteristics in AEC test hole 4. A packer was set in the lower part of the salt and the interval between 1186 feet and 1275 feet was tested. During this test the water level recovery was very slow indicating a very low permeability for the rocks in this interval. The interval between 650 feet and 1275 feet was tested for a period of 48 hours. During this test, water recovery was very slow, indicating a very low permeability for these rocks.

The Lower Cretaceous rocks were pumped for a period of 24 hours at a rate of 43 gpm. Drawdown at the end of the test was 17.94 feet. Specific capacity of the well was 2.4 gallons per minute per foot of drawdown. This well should yield about 250 gpm for short periods if pumped at its maximum capacity.

Area D-2 (AEC 5)

Location

Area D-2 is located in south-central Wichita County and includes the SE 1/4 Sec. 22, S. 1/2 Sec. 23, all of Sec. 26 and the E. 1/2 Sec. 27, T. 19S., R. 37W. AEC test hole 5 was drilled in the center of a 300 foot square in the SW cor. NE 1/4 Sec. 22, T. 19S., R. 37W. (Fig. 4).

Drainage

Area D-2 is drained by White Woman Creek and Sand Creek, which is a tributary to White Woman Creek. Neither of these streams flow except for short periods following very heavy precipitation. White Woman Creek flows into the "Scott Basin", and has no surface connection with trunk streams in this part of Kansas.

Geology and Topography

Topographically Area D-2 is a relatively flat, high-upland, area with a gentle eastward slope. The area has a gentle slope toward the principal streams and may become gently rolling near the streams. The upland area is underlain by 20 to 30 feet of loess, which thins to zero near the valleys of White Woman and Sand Creeks. The Ogallala Formation, which crops out only in the valley walls of these creeks, underlies the loess in the upland areas (Fig. 4). The average thickness of the Ogallala within a 5-mile radius of the 1440-acre site is about 80 feet; only locally is the Ogallala more than 100 feet thick in this area. However, the formation thickens considerably toward the west and north outside the 5-mile radius. In the valley areas, the Ogallala thins to less than 50 feet locally. The Ogallala in Area D-2 overlies the Niobrara Chalk of Upper Cretaceous age. In Area D-2 the Niobrara is about 210 feet thick. Several hundred feet of the Niobrara was eroded before deposition of the Ogallala. The rock units below the Niobrara and above the Morrison Formation of Jurassic Age and their thicknesses are: Carlile Shale, 240 feet; Greenhorn Limestone, 110 feet; Graneros Shale, 55 feet; and the Lower Cretaceous Dakota Formation, Kiowa Shale and Cheyenne Sandstone with a combined thickness of 360 feet.

Cultural Features

A graveled road runs through the 1440-acre site along the west side of sections 23 and 26, T. 19S., R. 37W. No buildings, power lines or communication lines are present on the site. A 10-inch high-pressure natural gas line owned by the Kansas-Nebraska Natural Gas Company runs in a northeast-southwest direction about 2 miles south of the 1440-acre site (Fig. 4). A 3-phase power line runs east-west along the north side of sections 22 and 23, and other single-phase and 3-phase lines serve other parts of the area within a 2-mile radius of the site (Fig. 4). Communication lines within the 5-mile radius are all overhead lines and are not shown on Figure 4.

Water Supply and Hydraulic Testing

One of the principal criteria considered in choosing this area for study was the general lack of large supplies of ground water. However, this area is well supplied with water for stock and domestic purposes, and several small irrigation wells are operated within a 5-mile radius of the site. An irrigation well 1/2 mile north of AEC 5 has a reported yield from the Ogallala Formation of about 490 gpm, a well in Sec. 1, T. 20S., R. 37W. yields 90 gpm and two wells in Sec. 28, T. 19S., R. 37W., each yield about 160 gpm. South and east from Area D-2, no irrigation wells are in operation except the one well in section 1 mentioned above. However, toward the north and west are numerous, wells all of which obtain water from the Ogallala Formation. Yields range from about 100 gpm to about 1000 gpm, with the larger yields from wells nearer the 5-mile radius on the north side of the area. Only the lower part of the Ogallala is saturated in this area, accounting for the low yield of the wells. An irrigation well was installed in NE 1/4 Sec. 22, T. 19S., R. 37W.; the depth to water before installation of the irrigation well was about 94 feet. In 1972 the water level stood at about 104 feet below the surface. The water level has been lowered 10 feet or about 25% of the saturated thickness since this well was installed. There probably has been a corresponding dcrease in yield from this well. In the northern part of the area within the 5-mile radius of site D-2 there has been considerable lowering of the water level and yields are reported to have decreased. The pumping test on the Ogallala Formation at AEC 5 was inconclusive. However, there was 15 feet of saturated sand and gravel in this well and a yield of about 100 gpm should be expected. Other than the Ogallala Formation, the only rocks having enough permeability to yield water to wells in this area of Kansas is the Dakota Formation. The Dakota has been tested in this general area in only a few wells, and its water-bearing characteristics are not fully understood. Well 19-38W-26dcc about 5 miles west of site D-2 yields water from the Dakota and has a reported yield of 300 gpm. However, the static water level on this well indicates that there may be communication with the Ogallala Formation, and the actual yield from the Dakota may be considerably less than the reported 300 gpm. The aquifer test on the Dakota Formation in AEC test hole 5 was inconclusive. With the static water level in the Dakota at 556 feet below land surface, the pump was set at 947 feet and pumped at a rate of 118 gpm. Within 10 minutes the well had drawn down to the pump and was losing suction. The well was allowed to recover and the pump again started at a rate of 70 gpm and within 10 minutes the water level had been drawn down to 825 feet. Water samples were collected and the test terminated. The water analyses indicate that drilling fluid may have been in the sample. The low yield and excessive drawdown during this test may have been caused by formation damage due to penetration of drilling fluids, insufficient or ineffective perforations, or poor formation characteristics. An injection test was made below the salt on the interval between 1950 feet and 2150 feet in AEC 5.

The packer was open for 48 hours and during the test the water dropped in the tubing 7.67 feet. About 1.9 gallons of water moved from the tubing to the formation during the 48 hour test, indicating a very low permeability for the interval tested.

An injection test was made on the interval between 1214 feet and 2150 feet. During the 48 hour test the water level in the tubing dropped 724.88 feet. In this test, about 176 gallons of water moved from the tubing into the aquifer at a rate of about 3.66 gallons per hour. This interval contains two separate zones of sandstone and to determine which zone was taking the water, the packer was again set to isolate the upper zone. This zone took very little water during the short test, indicating that most of the water was entering the sandstone between 1540 and 1570 feet.

Discussion

If only the cultural features (pipelines, power lines, homes and communication cables) in the three areas studied are considered, Area D-2 (AEC 5) rates above the other areas. These features are entirely lacking in Area D-2 but the entire area is under cultivation. Area A (AEC 3) would rate second, although it is the least accessible by road, and two pipelines traverse the area along the east border. This area is used almost entirely for grazing. Area A-1 (AEC 4) has two modern farmsteads and is almost entirely under cultivation.

If the hydrology of the three areas is considered, there is little difference between Areas A and A-1 both of which rate above Area D-2. The Cretaceous rocks in Area A yield somewhat more water than the rocks in Area A-1, but the water in Area A is of better quality than in Area A-1. The Permian rocks above and below the salt in both areas are quite impermeable. In Area D-2 water occurs in the Ogallala Formation and in the Dakota Formation; however, this water is isolated from the salt section by thick impermeable shales. The Permian sandstone in the interval between 1540 and 1570 feet has some permeability and is only 45 feet above the salt. Below the salt, the interval tested to 2150 feet was quite impermeable and from this depth to the top of the Stone Corral Formation it is quite likely that there is little permeability. The Stone Corral is about 10 feet thinner than the thickness generally reported for this unit in this area.

Chapter 3

WATER CHEMISTRY

by

Ernest E. Angino and Charles K. Bayne

General Statement

Water samples were obtained from selected aquifers present in AEC test holes 3 and 4 in Lincoln County and AEC 5 in Wichita County. Owing to some concern regarding water quality (for present and/or future use), routine tests were made using standard analytical methods. The chemical parameters for which measurements were made are indicated in Table 1. The results obtained for each well and aquifer are compared with Public Health Service potable water quality standards where applicable. This comparison is made with the clear understanding that most of the water would not be potable; however, the PHS standards realistically are those against which comparisons will be made--whether justified or not.

To make a detailed assessment of the meaning of the chemistry of the water encountered would be foolhardy. Of the 10 samples taken, the only good sample is (72142) from an irrigation well in the area of AEC 5. This water is from the Ogallala aquifer, a common source of water throughout western Kansas. All other samples show evidence of contamination (e.g. samples from AEC 4) and are not representative formation waters. The reasons for this situation may be several; however, the chemical data indicates that the wells were not properly prepared for taking a water sample. The wells seemingly were not flushed properly to remove the chemical additives introduced through the drilling fluid, or they were not pumped or swabbed long enough to obtain representative formation water. Contamination is indicated by high pH values for AEC 5 (samples 72143, 72144), high bicarbonate values for AEC 4, and high potassium values for AEC 3 and 4.

AEC 3

In AEC 3 samples 72137 and 72138 were obtained through the packer set at 969 feet. The interval tested was between 969 and 1100 feet and included the section below the salt. These samples were obtained by swabbing through the tubing. Because of the low permeability of the rocks in this interval, true formation samples were not obtained. Typically, this water should be a brine, but the analyses of samples 72137 and 72138 do not indicate a brine. It is probable that this water is principally water used to charge the packer and may possibly contain some drilling fluid.

Sample 72141 was taken from the interval between 406 and 1100 feet in AEC 3. The permeability of the rocks in this interval was low and a representative formation sample was not obtained. Typically, water from this section of rocks would be a brine. The sample probably contained flushing water and some residual drilling fluid.

Samples 72139 and 72140 from AEC 3 were from the Lower Cretaceous rocks between the surface and 406 feet. The samples were taken after the well was pumped for 12 hours and may be somewhat typical of the formation water from the entire section of Dakota and Kiowa rocks. Better quality water is generally available from the Dakota in this area. There is some indication from the analyses that residual drilling fluid is present.

AEC 4

In AEC 4 only the Lower Cretaceous rocks between 408 and 575 feet were sampled (72135-72136). The analyses indicate a high degree of contamination (K values) by drilling fluids. In the vicinity of AEC 4 the Cretaceous water generally is of poorer quality than at AEC 3. Farm wells in this area generally tap only the upper Dakota aquifer.

AEC 5

In AEC 5, samples 72143 and 72144 were obtained from the Lower Cretaceous rocks in the interval between 742 and 980 feet. Typically water, in this area from this section of rocks, should be a sodium bicarbonate-type. The analyses indicate residual drilling fluids to be present in the sample.

Sample 72142 was obtained from the Krenzel irrigation well in the interval between 100 and 135 feet. This water is from the Ogallala Formation and is typical of water from this formation.

Recommendations

Owing to these problems of contamination, a critical evaluation of the chemistry of water encountered cannot be made. In order to defend against charges of possible contamination of the aquifers, good samples of typical formation water are necessary to define background data and obtain proper baseline levels for water-quality evaluation.

In AEC 3, 4, and 5 the primary concern was to obtain geological information, hydrologic information related to quantity, and as complete a core of the salt section as possible. In drilling a test well from which many different kinds of information are to be obtained, maintaining "hole condition" is of primary concern to the driller. When drilling fluids are flushed from the hole with fresh water or brine and allowed to stand for considerable periods, there is a possibility that the hole may cave or "sluff", causing problems in achieving the primary objectives of the project. It is in part for this reason that poor water samples were obtained from AEC 3, 4, and 5.

Should additional studies related to a detailed evaluation of a potential site be undertaken, provision should be made for gathering baseline data on water quality from all aquifers. It is recommended that water samples be collected from holes drilled expressly for this purpose. These holes should penetrate all the more prolific aquifers and be drilled using only fresh water or fresh water mud.

If hydrologic testing and water sampling were to be done in a hole drilled expressly for this purpose, this work would proceed at the same time that the salt section is being cored in another hole. In Areas A and A-1, where only a single aquifer is present above the salt, it would be necessary to set only a short string of casing through the weathered surface rocks. Testing and sampling would be done in the uncased hole. If the hole is drilled with either fresh water or fresh water mud, it would be necessary to flush the well before testing long enough to remove cuttings and break down any mud cake on the borehole walls. The well should be pumped long enough that conductivity measurements indicate formation water is being obtained.

If hydraulic testing and water sampling are to be done from the same test well in which the salt is to be cored, it would be desirable to drill through the aquifer with fresh water or fresh water mud, flush the hole and proceed with hydraulic testing and water sampling. However, this procedure might not be acceptable to the driller. After this testing was completed, casing should be set and cemented, and drilling or coring continued.

Hydraulic testing in the zones of low permeability above and below the salt should be done in the test well after coring is completed.

Table 1 gives the analyses of samples of water collected from AEC 3, 4, 5 and the Krenzel irrigation well.

[redacted]

Table 1.--Analyses of Water Samples from AEC 3-4-5 and Krenzel Irrigation Well

Sample No.	AEC 3 72137	AEC 3 72138	AEC 3 72139	AEC 3 72140	AEC 3 72141	AEC 4 72135	AEC 4 72136	AEC 5 72142	AEC 5 72143	AEC 5 72144	PHS drinking water standards
Bicarbonate (HCO_3)	43	44	347	349	33	11,580	11,595	193	204	208	
Calcium (Ca)	149	149	39	34	87	370	368	60	23	25	
Magnesium (Mg)	27	25	14	12	12	542	512	34	6	5	
Potassium (K)	175	190	10	12	13	115	115	7	23	22	
Sodium (Na)	70	75	500	390	1,950	6,800	7,800	34	300	290	
Sulfate (SO_4)	280	293	216	215	210	2,087	2,091	91	329	314	250
Phosphate (PO_4)	0.1	0.1	0.1	0.2	< 0.1	0.5	0.5	0.1	0.1	0.1	
Nitrate (NO_3)	3.9	4.4	0.5	0.6	2.5	1.4	1.4	14.2	3.8	3.6	10
Chloride (Cl)	330	340	250	250	900	4,600	4,000	90	82	66	250
Fluoride (F)	< 0.1	< 0.1	2.3	2.3	0.2	0.4	0.4	0.2	2.8	2.7	1.5
Total Solids (TS)			1,575	1,806?				578	2,076	2,017	
Dissolved Solids (DS)	1,299	1,298	1,411	1,877?	5,559	27,332	27,351	503	1,399	1,124	500
Volatile Solids (VS)			263	376				169	445	402	
pH	6.5	6.5	8.1	8.2	6.7	7.5	7.8	7.7	8.9	9.0	6.0-8.5
Type sample			Fresh	Fresh	Brine	Brine	Brine	Fresh	Fresh	Fresh	
Depth	969-1100	969-1100	0-406	0-406	406-1100	408-575	408-575	100-135	742-980	742-980	
Source	Test Well	Test Well	Test Well	Test Well	Test Well	Test Well	Test Well	Irrigation pipe	Test Well	Test Well	
Carbonate									452	453	
Geologic Source	Permian		Dakota- Kiowa		Permian	Dakota- Kiowa		Ogallala	Dakota	Dakota	

Note: Analyses reported in parts per million (ppm). Public Health Service standards are in milligrams per liter (mg/l.). Values in ppm and mg/l. are approximately the same for waters of low concentrations (< 5000 ppm).

Chapter 4

SUBSURFACE ANALYSIS OF POSSIBLE ALTERNATE SITES

by

Edwin D. Goebel

General Comments

The taking of three Permian salt cores, two in the Hutchinson Salt in Lincoln County and one in the younger Blaine-Cedar Hills salt in Wichita County, as part of the three-hole reconnaissance core-drill program, for possible alternate storage vaults for radioactive waste yielded important new geologic data on the distribution, thickness, and rock characteristics of Kansas bedded-salt deposits. The thickness and quality of the salt beds are now known at the three possible alternate sites. Additionally, the new data on thickness and quality, alter earlier regional interpretations based on less information.

From the earlier reconnaissance study of 8 possible areas (Angino, et al., 1972), the three cored areas were selected for coring on the basis of the possible presence of more than 200 feet of salt section at AEC 3 and 4 locations and more than 400 feet of salt section at AEC 5. The basis of the geologic data used in the Angino study was oil and gas exploration information. The data from Lincoln County involved old cable tool holes drilled in the 1920's and 1930's. It is now clear that the use of some of these cable-tool data, and much of the rotary drilling and scouting data, unsupported by gamma ray and neutron logs, resulted in spurious and unreliable thickness contour maps of the salt section. In general, where the thickness of salt section maps (Angino, et al., 1972) are based on these types of data, there is need for reduction of total thickness, eliminating some of the anhydrite and shale beds commonly present in the top portion of the evaporite section.

Figure 5 is a revised isopachous map of the salt section at AEC 3 and 4 in Lincoln County and Figure 6 is a similar map for AEC 5 in Wichita County. All well locations were rechecked and all new drilling information to August 21, 1972 was added to Figures 5 and 6. Figures 5 and 6 serve as index maps to logs of boreholes used by Dellwig in Chapter 5 of this report. At AEC 3, there is 157 feet of salt section; at AEC 4, 165 feet and AEC 5, 420 feet (including 60 feet of salty sandstone at base). Salt intervals selected as possible mine and storage spaces are presented by Dellwig (this report) and Stubbs (Geological Logs) and generally, the proposed "good" sections are in the same intervals. The criteria (Table 4, No. 3.3) of greater than 10 miles to the salt margin is not met in Lincoln County.

Fracturing of non-salt beds, as reported in AEC coreholes 1 and 2 from the Lyons site, Rice County (Angino and Hambleton, 1971, p. 73), was not observed in the cores from AEC 3, 4, or 5. Some of these features may be present but are not discernible from the curved surfaces of the cores.

The depths to the top of the salt section in Lincoln and Wichita counties were close to those predicted by the thickness of overburden maps in the 8-area, reconnaissance study by Angino, et al., 1972. The criterion (Table 4, No. 1.9) of greater than 700 feet to the top of the salt beds and less than 2500 feet to the disposal horizon are met. It is judged unnecessary to revise those maps for Lincoln or Wichita counties.

The relief of the salt beds at the prospective mining horizons (Table 4, No. 2.1), was not specifically investigated. The small numbers of data control points and the limiting factor of one cored section at each potential site, placed great restraints on projection of a mining horizon of less than 100 feet/mile (about one degree of geologic dip).

Regional tectonic stability (Table 4, No. 2.4) was not considered in this study. Some relative data were given in Angino and Hambleton, 1971 (p. 63-66).

Comments on New Information Generated by Coring

The revised isopachous maps were prepared with a 50 foot contour interval rather than the 10 foot interval used in the earlier reconnaissance study. A larger contour interval is justified on the basis of few data control points in the general vicinity of AEC 3 and 4 coreholes and the fact that broad regional trends are more discernible using the larger interval. Those trends include an obvious regional thinning of the salt section from more than 250 feet on the southwest (Fig. 5) to an approximated zero line on the northeast. Also, there is an apparent northwest-southeast alignment of contour lines seemingly indicating a dependable and gradual thickening basinward to the southwest. Three areas of greater than subregional thickness occur to the east and northeast of AEC 4. Information on the closest of these thicker areas to AEC 4 comes from two cable drill holes drilled in 1921 and 1926. The other subareas are farther removed from AEC 4 and are of less value in projecting section thickness toward the east. The thick section (170') in Sec. 35, T. 10S., R. 8W. is based on a reliable log of the hole designated by the Kansas Geological Society as the type stratigraphic log for Lincoln County.

Two large areas of thinning are present southwest of the AEC 3 site. Except for these two areas, there is reasonable assurance of the presence of greater than 150 feet of salt section southwest of a line drawn from the mine shaft at Kanapolis through the site of AEC 3 and 4 and extended to the northwest corner of Figure 5. The salt section probably thins gradually to the northeast from AEC 3. Toward the northeast from AEC 4 possibly the salt section increases to more than 200 feet.

Should the area in the vicinity of AEC 3 be chosen for additional evaluation, and should more than the 157 feet of salt section known now to occur there be required, the site could be shifted (based on these criteria only) toward the northwest or toward south by southeast. Any of the area within a mile along a line from the Kanopolis mine (Sec. 25, T. 15S., R. 8W.) to near the location of AEC 3 would probably contain a slightly thicker (up to 50 feet) salt section. On a regional basis (Fig. 5) the increased section is in the lower part of the salt beds. On a local basis, Dellwig (Chapter 5, Fig. 7), the salt section is thicker at the top, westward from AEC 3.

Should the area in the vicinity of AEC 4 be chosen for additional study and evaluation, the location reasonably could be shifted about 11 miles toward the west, with greatest relative confidence of the occurrence of a thicker section near the abandoned dry hole in Sec. 33, T. 11S., R. 12W., Russell County.

Shifting of the sites from AEC 3 or 4 is not advocated on the basis of positive knowledge of thicker sections between core holes. Rather, the projected thicknesses into unknown areas are derived from available subsurface-data-control points. All subsurface thickness and structural maps have this same inherent aurora of speculation; all such maps are interpretations.

The 420 foot thickness of the "salt section" predicted for the Wichita County area in Figure 57 of Goebel _et al_. _in_ Angino, _et al_. (1972) was verified by the AEC 5 core (Fig. 6). The quality of salt from AEC 5 was lower than interpreted from geophysical logs in the area. The lack of lamination or bedding in the salt section was not predicted. The red color of contained clay- and silt-sized particles was expected. The red colored salt, and the 60 foot thick section of approximately 65% insoluble "red-rock, salt-silt to sand" at the bottom was known from a core description in Sec. 12, T. 26S.,

R. 38W., about 45 miles south of AEC 5. That core could not be located for study. An x-ray pattern of the "red-rock, salt-silt to sand" section (AEC 5) indicated quartz and minor feldspar. Preliminary insoluble residue determinations give a 35/65 ratio of salt to non-salt in the lower part of AEC 5 core. Additional residue study is reported by James (Chapter 6).

Should the area of AEC 5 be chosen for more evaluation, no shift of location to attain a greater thickness would be necessary.

Oil and Gas Exploration

Near the town of Ellsworth (south of AEC 3 in T. 15S., R. 8W.) several new gas wells in the Lansing Group (Pennsylvanian) at 2500 feet depth (well below the salt section) have been completed in recent months. An old gas well (Sec. 26, T. 15S., R. 8W.) north of Ellsworth has produced gas from a depth of 1095 feet which is within the Permian rocks but below the salt section. Neither of these are of immediate impact on the AEC 3 site, unless it is shifted toward Kanopolis.

A new oil well in Sec. 31, T. 19S., R. 34W. to the east of AEC 5 has been completed in the Marmaton rocks (Pennsylvanian). This is 14 miles east from the location of AEC 5.

Recommendations

1. If the Lincoln County area is considered as the location of an alternate site, the location and nature (depositional

or dissolutional, Table 4, No. 3.4) of the salt section in the vicinity need to be investigated. Use of geophysical exploration methods should be fruitful in such a study.

2. Investigate the relationship of the heights of the hydraulic heads on brine reservoirs stratigraphically below the salt section, but which could rise as high as the salt section and possibly be an endangering factor to its integrity.

Chapter 5

SALT SEQUENCES

by

Louis F. Dellwig

AEC 3

Salt in AEC 3 is of the same general character as that encountered in AEC 1 and 2 (Table 2). Although of lesser thickness and purity, it is of the same general type as the widespread Salina salt of the Great Lakes region and the Louann Salt (now best exposed in a deformed state in domes) of the Gulf Coast. As is characteristic of salt deposits of this type, lateral continuity of at least major stratigraphic breaks is to be expected, this being demonstrated by correlation of the logs of AEC 3 and the adjacent Siegel (5 1/2 mi. SW and Rahmeier (7 mi. NW) wells (Fig. 7).

Some loss in salt in AEC 3 is to be noted at the top of the section (Fig. 7). The missing salt section is marked by an anhydrite-shale breccia zone, immediately above which the sequence is horizontal (Plate 1). Solution apparently occurred before the deposition of the sequence overlying the breecia zone; the development of the breccia does not appear to be associated with Recent groundwater activity. Overall, the sequence containing salt is less than 160 feet thick.

Zones of insolubles in the salt section are shown to scale if over 1 foot thick (Fig. 8, Table 3). Salt zones of reasonably good quality salt are identified by thickness. Zones

Table 2.--Depth, Thickness and Lithology of Salt Section on AEC 1

Depth (ft)	Thickness (ft)	Lithology
1021.5 - 1021.53	0.03	shale
1021.53 - 1021.8	0.27	salt
1021.8 - 1021.83	0.03	shale
1021.83 - 1023.0	1.17	salt
1023.0 - 1023.2	0.2	shale
1023.2 - 1025.1	1.9	salt
1025.1 - 1025.2	0.1	shale with salt
1025.2 - 1026.7	1.5	salt
1026.7 - 1026.72	0.02	shale
1026.72 - 1027.5	0.78	salt
1027.5 - 1028.6	1.1	salt and shale
1028.6 - 1032.5	3.9	salt with anhydrite and shale laminae
1032.5 - 1033.6	1.1	salt with polyhalite
1033.6 - 1034.95	1.35	salt
1034.95 - 1034.97	0.02	shale
1034.97 - 1035.1	0.13	salt
1035.1 - 1035.12	0.02	shale
1035.12 - 1037.55	2.43	salt
1037.55 - 1038.3	0.75	shale, anhydrite and salt
1038.3 - 1045.0	6.7	salt
1045.0 - 1045.01	0.01	shale
1045.01 - 1046.4	1.39	salt impure
1046.4 - 1055.45	9.05	salt pure
1055.45 - 1055.7	0.25	shale
1055.7 - 1059.15	3.45	salt with clay
1059.15 - 1059.8	0.65	shale
1059.8 - 1060.25	0.45	salt
1060.25 - 1063.8	2.55	shale

Note:

1) For reference only; Depth and thicknesses are not adjusted to Gamma Ray log.

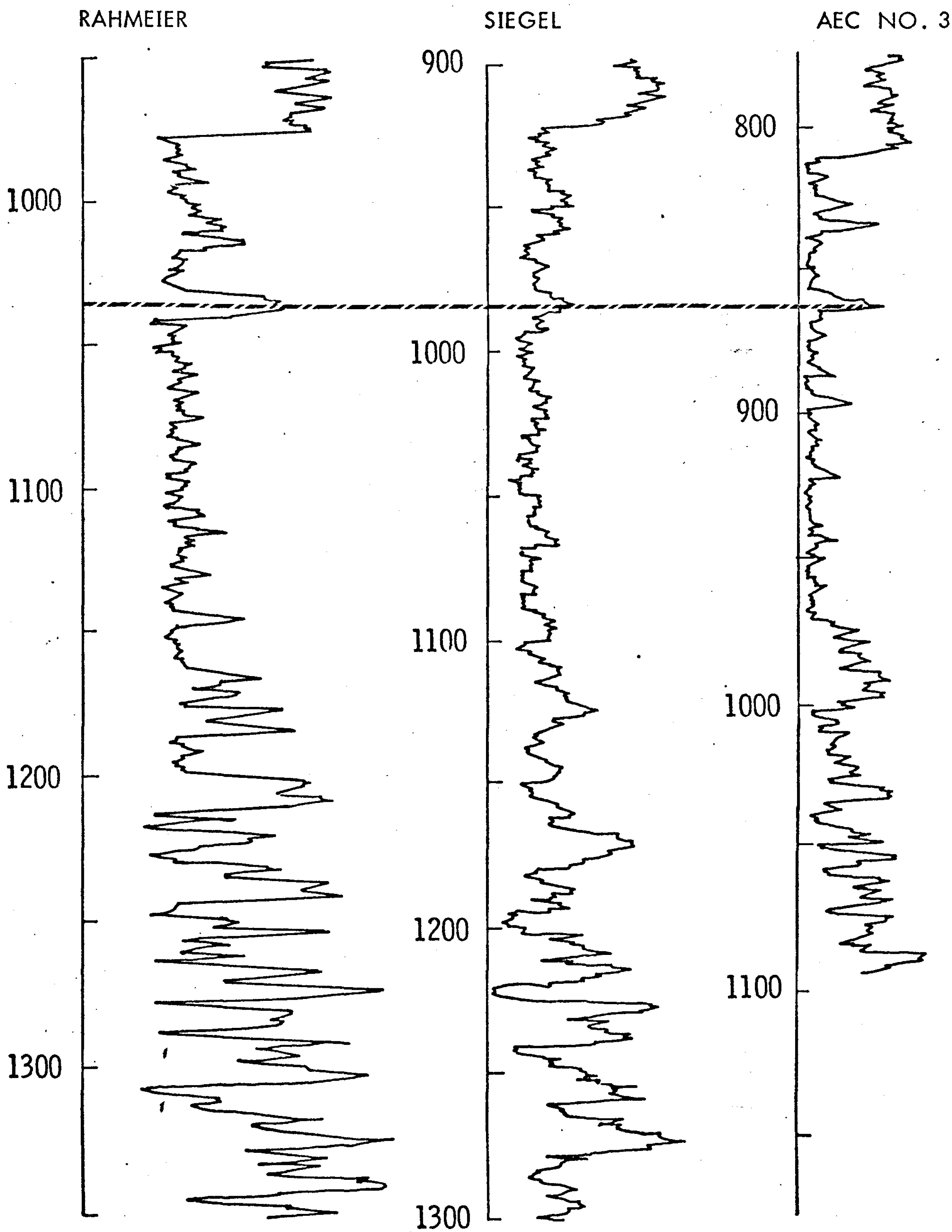


Figure 7.--Correlation of AEC 3 Test Hole and the Siegel and Rahmeier Wells.

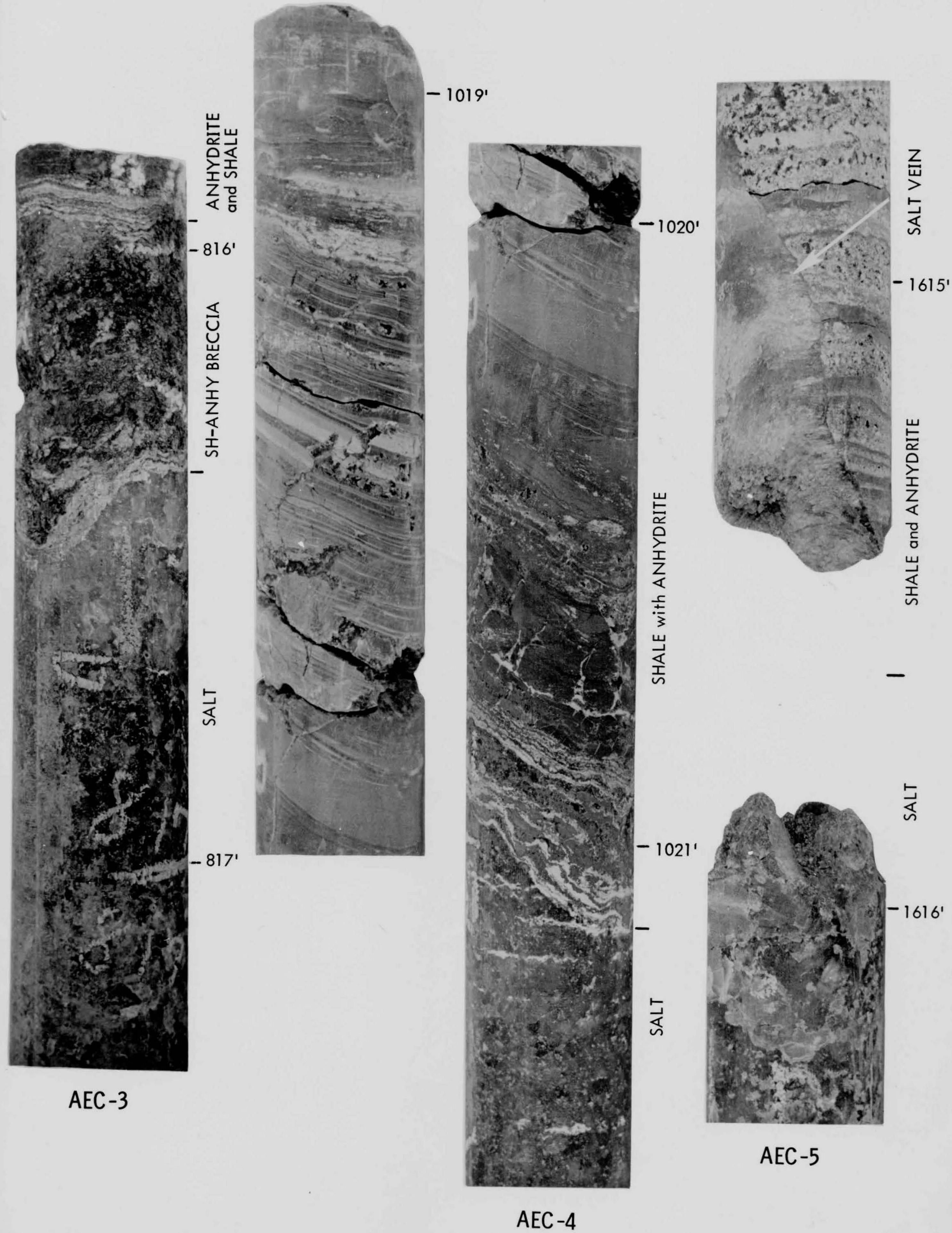


Plate 1.--Anhydrite-Shale and Salt Contact in AEC 3, 4 and 5.

No. 3 AEC Test Hole

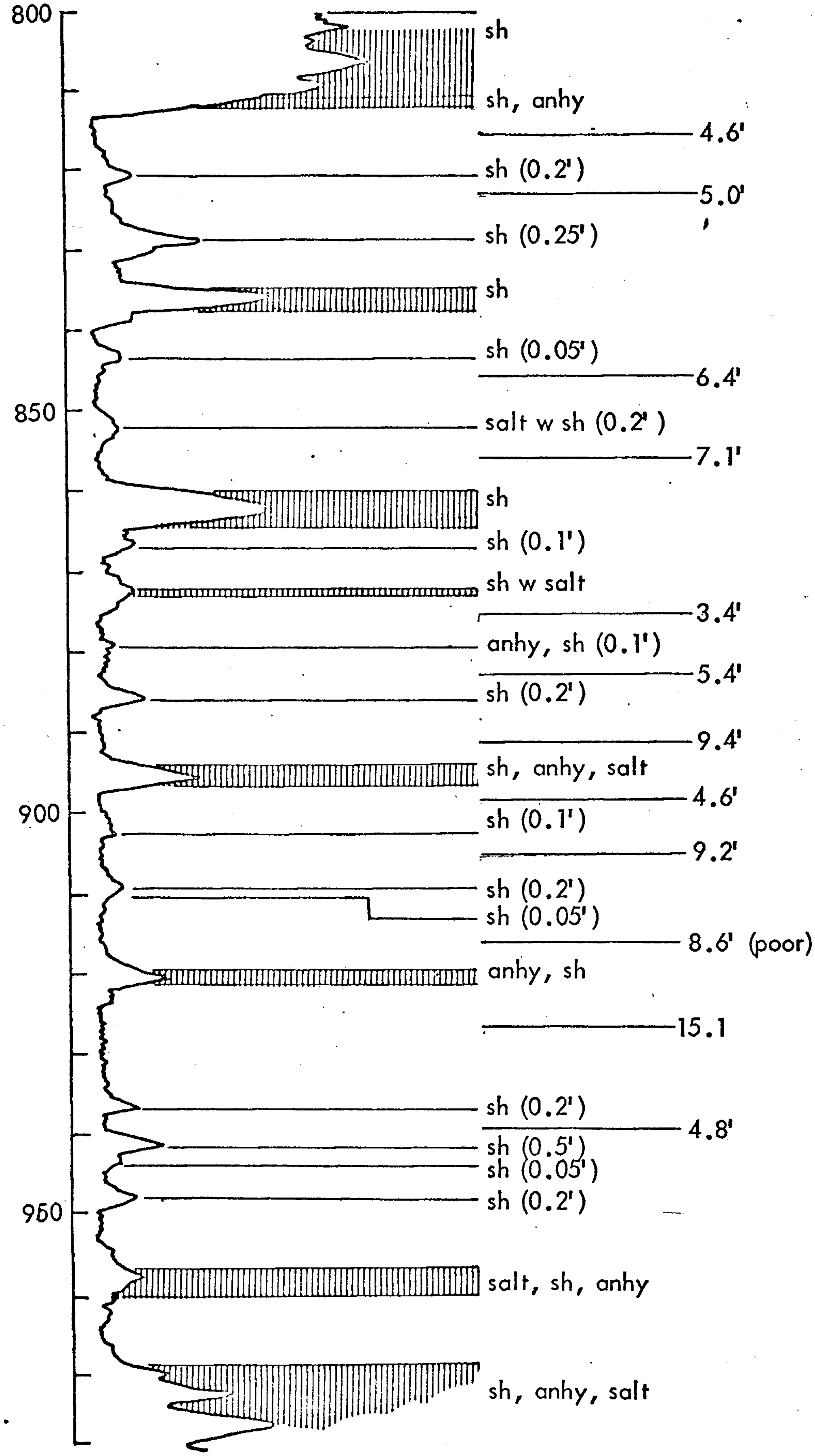


Figure 8.--Zones of Insolubles and Thicknesses of Reasonably Good Quality Salt in AEC 3.

Table 3.--Depth, Thickness and Lithology of Salt Section on AEC 3

Depth (ft)	Thickness (ft)	Lithology
874.6 - 876.6	2.0	salt-shale mix
876.6 - 880.0	3.4	salt, 6-8% insolubles
880.0 - 880.08	0.08	anhydrite and shale
880.08 - 885.6	4.52	salt, 4-7% insolubles
885.6 - 885.8	0.2	red and gray shale
885.8 - 887.1	1.3	salt, 30% insolubles
887.1 - 894.4	7.3	salt, 3-5% insolubles
894.4 - 894.6	0.2	shale
894.6 - 895.4	0.8	salt and shale
895.4 - 895.5	0.1	shale; minor anhydrite
895.5 - 896.2	0.7	shale; minor anhydrite and salt veins
896.2 - 901.8	5.6	salt, 4-6% insolubles
901.8 - 901.85	0.05	irregular anhydrite band
901.85 - 902.7	0.85	salt, 6-8% insolubles
902.7 - 902.8	0.1	shale
902.8 - 909.6	6.8	salt, 4-6% insolubles
909.6 - 909.8	0.2	shale
909.8 - 910.8	1.0	salt
910.8 - 910.85	0.05	shale
910.85 - 913.4	2.55	salt
913.4 - 913.42	0.02	shale
913.42 - 920.0	6.58	salt, 4-6% insolubles
920.0 - 921.2	1.2	brecciated anhydrite and shale
921.2 - 922.6	1.4	salt
922.6 - 922.62	0.02	shale
922.62 - 924.2	1.58	salt
924.2 - 931.3	7.1	salt, 6-8% insolubles
931.3 - 936.85	5.55	salt, 2-4% insolubles
936.85 - 937.2	0.35	shale
937.2 - 941.9	4.7	salt, 1-3% insolubles
941.9 - 942.4	0.5	shale

Note:

1) Depth and thicknesses adjusted to Gamma Ray log.

2) Percent insolubles estimates are visual.

in which no thickness is shown are too thin, or of too poor quality to be considered because of either a high percentage of dispersed shale or excessive banding. Lined zones are zones which include excessive amounts of shale or anhydrite. Depths in Figures 8, 10, and 12 are log-depths with core lithologies and marked depths adjusted to match. The maximum adjustment is 4 feet. Depths on Plate 1 are as marked on the core.

In the preliminary report of June 30, 1972, three zones of potential interest for radioactive waste storage were defined in the AEC 3 core. These zones were defined on the basis of thickness, purity and mineability in terms of shale partings, potential roof, etc., and assuming that the overall thickness would be acceptable. Core from these zones has since been reexamined and, in the light of the Site Criteria as defined in the Oak Ridge National Laboratory's document of March 1, 1972, (ORNL Central files 72-3-4) (Table 4), elimination of two zones from consideration is recommended for the stated reasons:

ZONE		CRITERIA NOT MET
876.6-894.4	1.3	Thickness of salt above disposal horizon is < 75'.
	1.5	Thickest unit without shale partings, in excess of 1/4" is < 10'.
896.2-920.0	1.3	Thickness of salt above disposal horizon is < 100'.

Table 4.--Site Criteria*

Number	Item	Criteria
1.2	Thickness of salt formation	> 200 ft
1.3	Thickness of salt above disposal horizon	> 150 ft
1.4	Purity of salt formation	> 150 ft equivalent thickness of pure salt
1.5	Stratigraphy of disposal horizon	> 12 ft thick, > 95% NaCl, no shale partings
1.6	Stratigraphy of mining horizon	Minable
1.9	Depth to top of salt formation	> 700 ft
1.10	Depth to disposal horizon	< 2500 ft
2.1	Relief of salt formation	< 100 ft/mile
2.2	Topographic relief	< 100 ft/mile
2.4	Tectonic stability	USC&GS Zone 0 or 1
3.3	Horizontal extent of salt deposit	> 10 miles to boundary
3.4	Horizontal isolation from dissolutioning boundary	> 20 miles
4.2	Salt mining operations	> 5 miles distant

* This table lists the criteria considered by ORNL document, Central File No. 72-3-4, March 1, 1972. This document states: "It should be emphasized that the various criteria and the numerical values attached to them are not rigid and unalterable. They are simply the current best estimates and are subject to revision as additional information becomes available".

1.5 Thickest unit without shale partings, in excess of 1/4" is < 10'.

Thickest unit is < 95% NaCl.

The third unit 921.6-941.9 contains one sequence unbroken by a significant shale parting (924.2-936.9) of 12.7' of approximately 94-96% NaCl (visual estimate). This unit is immediately overlain by 3.0' of impure, nearly opaque salt above which is approximately 2.0' of brecciated anhydrite and shale interlaced with red salt veins. Thus, this unit is at best, marginal; especially in the light of the low overall thickness and purity and poor definition of this zone in adjacent wells. As a result of reexamination of these three sections, I do not feel that this core targets any sequence which has reasonable potential as a storage zone.

AEC 4

Salt in AEC 4 is also typical of the Hutchinson. Correlation with the Thurston well (7 mi. NW) (Fig. 9) is good and, as in the case of AEC 3, continuity of major shale and anhydrite units within the salt section is to be expected. The loss of salt at the top of the section is marked by an unconformity within the salt section itself (indicative of solution of salt by freshened basin waters prior to temination of salt deposition) and by a thin solution breccia within the overlying anhydrite-shale sequence (Plate 1). Overlying beds are horizontal within 2 feet of the top of the salt

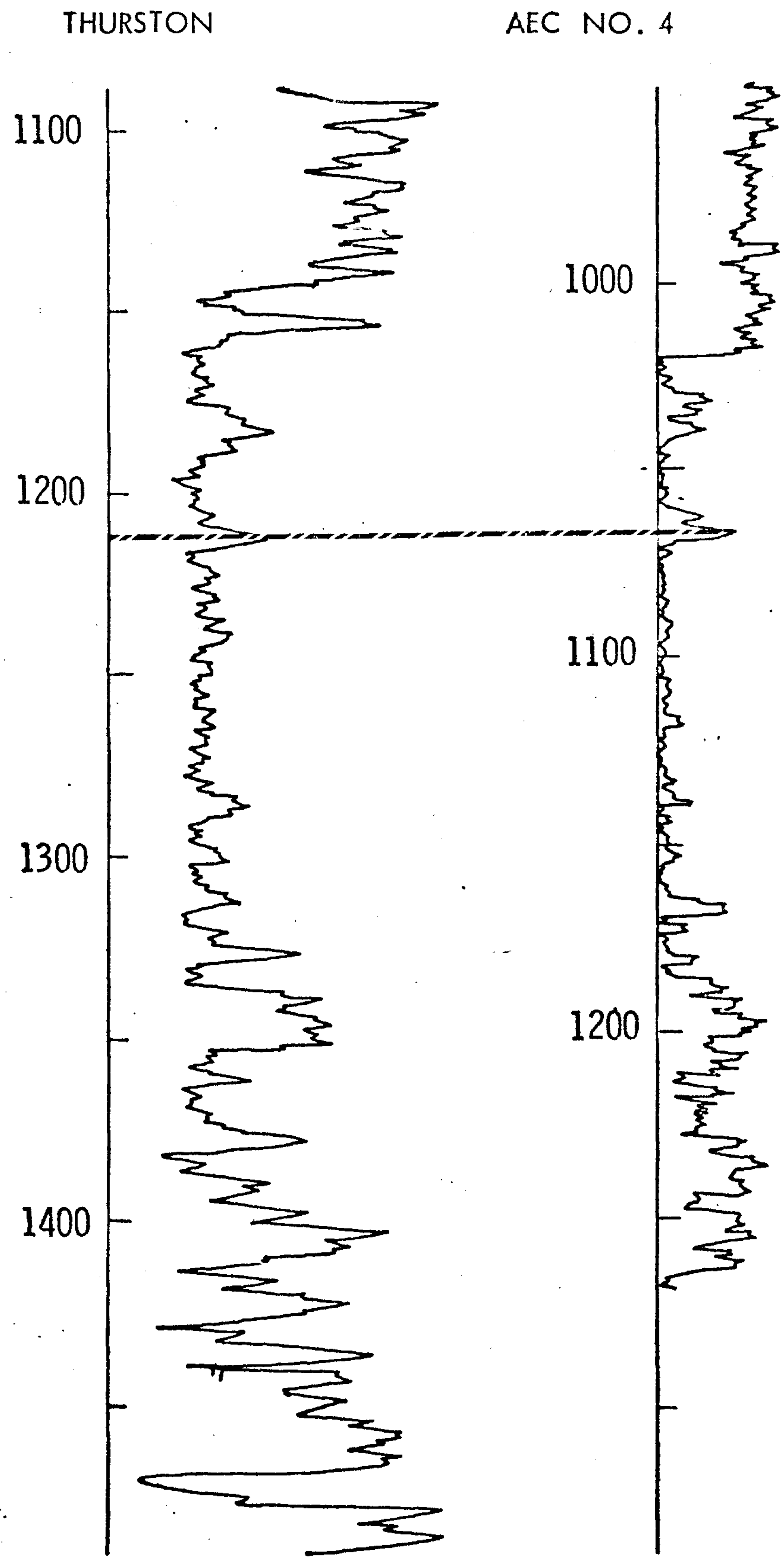


Figure 9.--Correlation of AEC 4 Test Hole and Thurston Well.

section the adjustment being made by depositional, not deformational processes. There is no evidence of solution by Recent groundwater activity.

Coding of Figure 10 is the same as in Figure 9.

The two zones (Fig. 10 and Table 5), initially targeted as potential storage zones, were reexamined and both are now rejected for the following reasons:

ZONE		CRITERIA NOT MET
1073.0-1092.8	1.3	Thickness of salt above disposal horizon is < 100'.
	1.5	Thickest zone unbroken by shale parting not in excess of 1/4" and of 95% purity is < 7'. (This can be extended to 12.5' if one 3/8" shale band is included. The combined unit is overlain by 0.8' of a shale-salt sequence.)
1096.0-1118.4	1.5	Thickest zone unbroken by shale partings and of 95% purity is 7.5 feet. Purity of the remainder of the zone is < 95% NaCl.

Storage potential at this site as indicated by this core was initially rated as less than that at the AEC 3 site; reexamination of the cores has confirmed the original observation.

Table 5.--Depth, Thickness and Lithology of Salt Section on AEC 4

Depth (ft)	Thickness (ft)	Lithology
1072.15 - 1072.3	0.15	shale
1072.3 - 1072.4	0.i	salt
1072.4 - 1072.44	0.04	shale
1072.44 - 1072.85	0.41	salt
1072.85 - 1072.95	0.1	shale
1072.95 - 1079.9	6.95	salt, 4-6% insolubles
1079.9 - 1079.93	0.03	shale
1079.93 - 1087.3	7.37	salt, 4-6% insolubles
1087.3 - 1087.35	0.05	shale and anhydrite
1087.35 - 1091.8	4.45	salt, 4-6% insolubles
1091.8 - 1092.2	C.4	shale bands in salt
1092.2 - 1092.6	0.4	salt
1092.6 - 1092.8	0.2	shale
1092.8 - 1094.3	1.5	salt
1094.3 - 1094.5	0.2	shale
1094.5 - 1095.9	1.4	salt with polyhalite
1095.9 - 1095.98	0.08	shale
1095.98 - 1099.2	3.22	salt, 4-6% insolubles
1099.2 - 1100.75	1.55	salt, 8-10% insolubles
1100.75 - 1100.8	0.05	anhydrite
1100.8 - 1101.2	0.4	salt and anhydrite, 30% insolubles
1101.2 - 1101.45	0.25	shale
1101.45 - 1109.3	7.85	salt, 4-6% insolubles
1109.3 - 1109.4	0.1	shale
1109.4 - 1109.9	0.5	salt
1109.9 - 1110.1	0.2	shale
1110.1 - 1118.4	8.3	salt, 7-9% insolubles
1118.4 - 1118.7	0.3	shale

Note:

1) Depth and thicknesses adjusted to Gamma Ray log.

2) Percent insoluble estimates are visual.

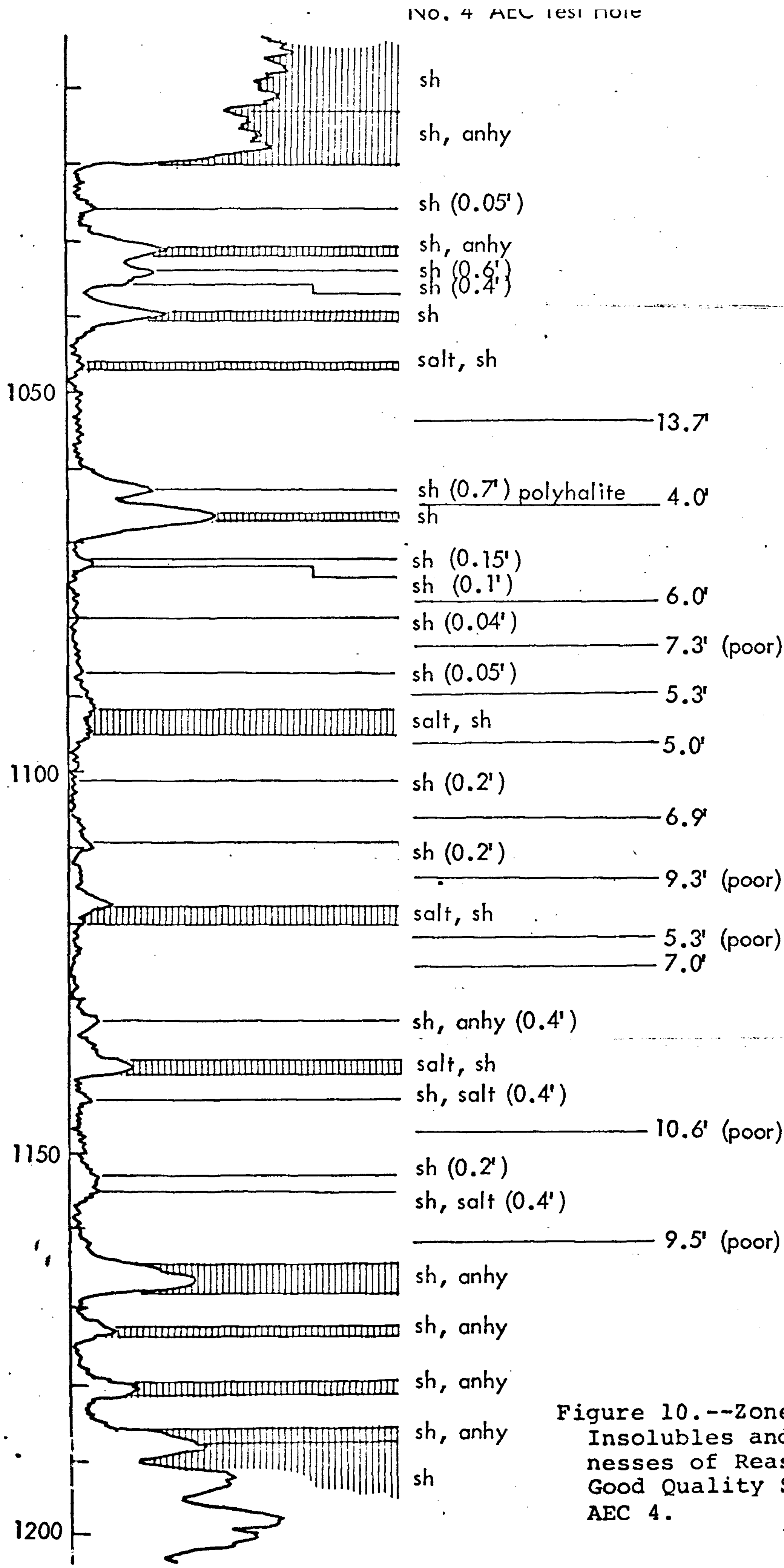


Figure 10.--Zones of Insolubles and Thicknesses of Reasonably Good Quality Salt in AEC 4.

AEC 5

AEC 5 cut a salt-red bed sequence below the Blaine Anhydrite. The sequence contrasts strongly with the Hutchinson Salt both in character and quality. Although correlation with the nearby Mantel (6 1/2 mi. NE) and Lehner (4 1/2 mi. SE) wells appears to be reasonably good (Fig. 11), lateral continuity is not to be expected. The transition zone from salt to anhydrite deposition at the top of the core (Plate 1) is a lost section, but the horizontality of the anhydrite indicates that no Recent solution has taken place. Unlike the Hutchinson, salt crystals in this sequence appear to have grown in soft bottom muds with the result being relatively clear, clean crystals with interstitial rather than dispersed impurities. Banding is essentially absent except in some thick shales, and "fine stratigraphy" is non-existent. As stated elsewhere in this report (James, Chapter 6) the impurities are predominately clays and anhydrite, in general, in an unbedded state.

Where shale is indicated (Fig. 12) bedding in the claystone is visible, generally confined to sequences of alternating shale and anhydrite. Where the interstitial clay is essentially homogeneous and structureless it is defined as clay. From the point of view of mineralogy the materials are essentially the same.

Sections of anhydrite or shale in which the clay content exceeds 20 percent are blocked out (Fig. 12) and estimated clay content for the remainder of the salt section is indicated in percent clay. Laboratory analyses essentially substantiate the visible estimate. The remainder of the coding is as in Figures 8 and 10.

This sequence in its entirety fails to meet the following requirements:

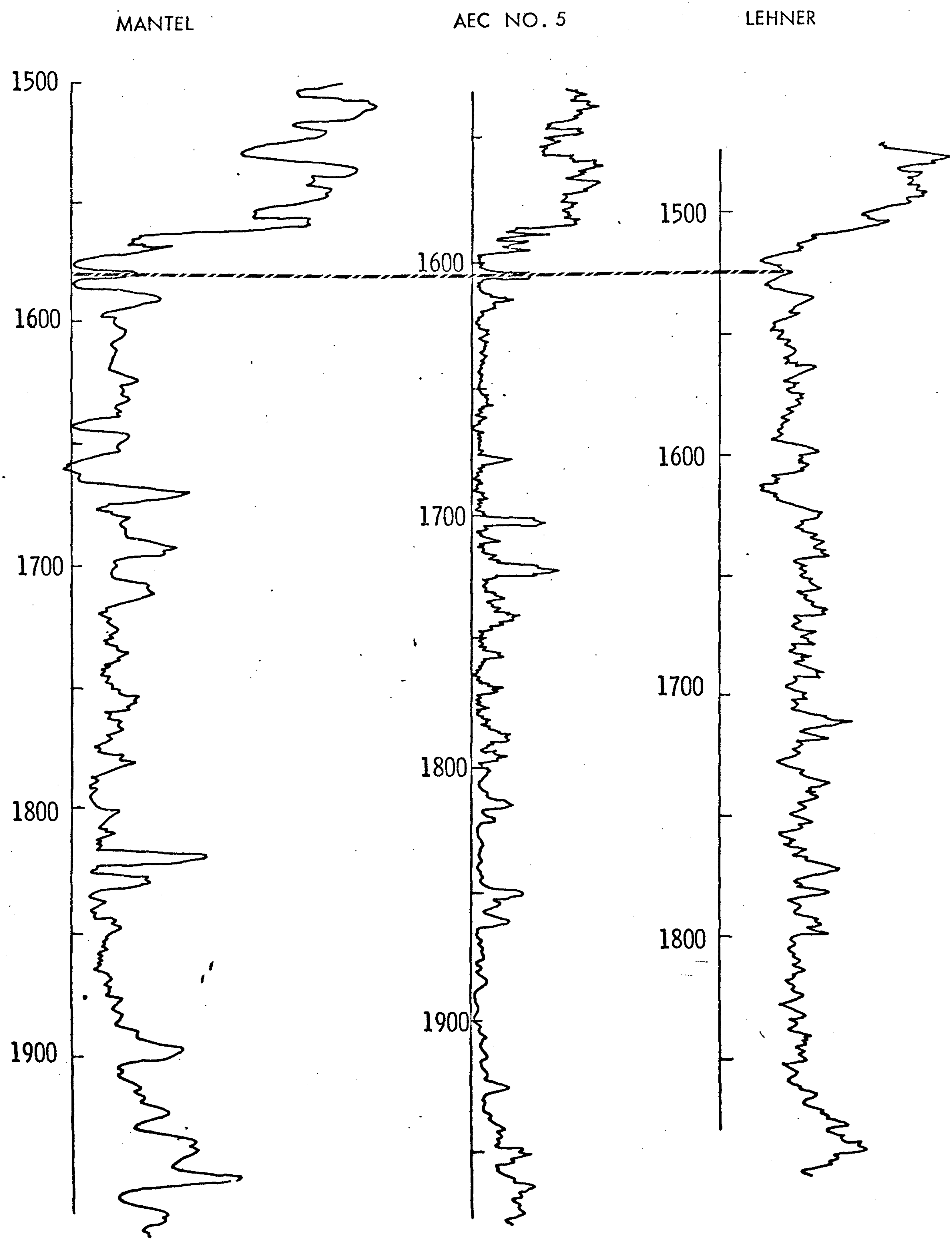
1.5 Stratigraphy of disposal horizons. The only sections of > 95% purity in excess of 12' thick are within 60' of the top of the section.

1.6 Stratigraphy of mining horizons. Interstitial clays would cause weakness in pillars and roof.

4.2 Salt mining operations. Salt would not be saleable and would be difficult to dispose of.

Overall high clay content, paucity of sections with low clay content, and suspected lack of continuity of units suggests that no further consideration be given to this unit.

Figure 11.--Correlation of AEC 5 with the Mantel and Lehner Wells.



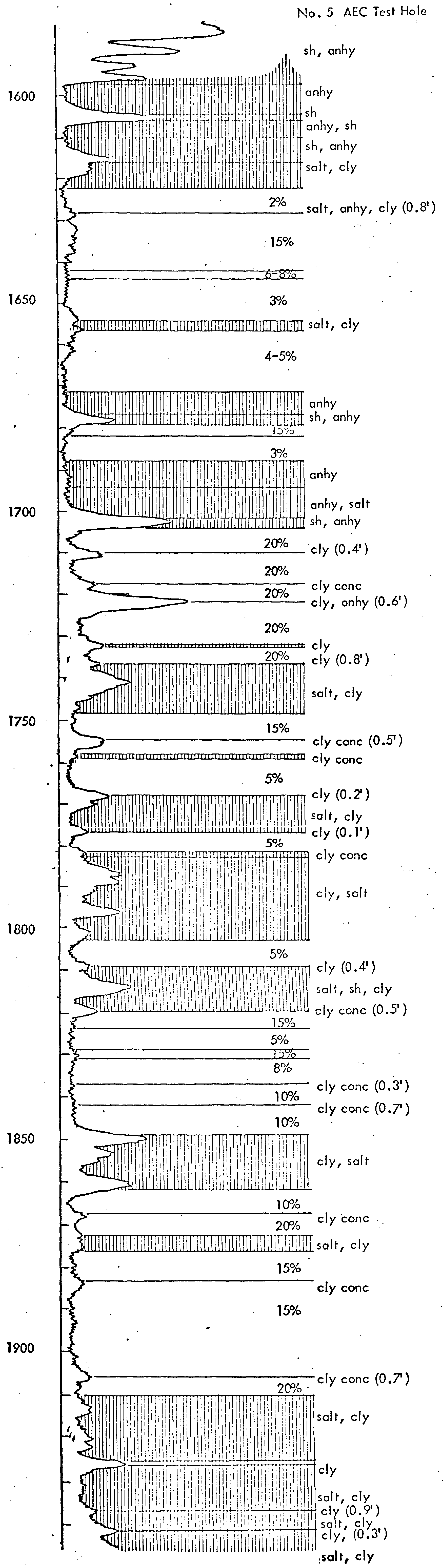


Figure 12.--Zones of Anhydrite or Shale and Percent of Clay in AEC 5.

Chapter 6

MINERALOGY AND DISTRIBUTION OF WATER-INSOLUBLE RESIDUES FROM AEC TEST HOLE 5

by

Gerard W. James

Summary

Insoluble residue analyses of samples collected from AEC test hole 5 indicate the overall salt purity of the 346 foot salt section may be on the order of 80%. Two 30 foot sections (1622-1652' and 1820-1850') appear to contain 90 to 95% salt; only portions of the upper 30-foot interval appear to have greater than 95% pure salt.

The red, fine-grained, water-insoluble material is concentrated around salt crystal boundaries and frequently tends to be concentrated in small zones ranging from a few inches to a few feet in thickness. X-ray diffraction analyses of 25 selected samples indicate the water-insoluble material may be predominantly anhydrite ($CaSO_4$), dolomite [$(Ca,Mg)CO_3$], magnesite ($MgCO_3$), or clay minerals (swelling chlorite and illite), or combinations of these minerals. Petrographic observations indicate the bulk of the insoluble material occurs in the clay to fine-medium, silt-size range (less than 30 microns). The water-insoluble material exhibits little tendency to have small-scale layered textural features and should be called claystone or mudstone.

Although detailed clay-mineralogic analyses were performed on only two samples, it should be noted that both

contained significant amounts of swelling chlorite, an expanding-lattice layered silicate, which may exhibit heat exfoliation properties, and has the ability to lose or gain interlayered water as temperatures and humidities change. Swelling chlorite was indicated in most other samples, but tests to prove this have not been conducted. If AEC test hole 5 appears to meet all criteria for a high-level radioactive waste repository, potential zones should be resampled for ore representative insoluble-residue analyses, and the effects of the expanding-contracting lattice properties of the swelling chlorite impurities should be given significant evaluation. These properties will generate a strong influence on the structural design of a salt-vault.

Insoluble Residues

Preliminary examination of the logs and core from AEC test hole 5, (22-19S-37W, Wichita County, Kansas) by AEC consultants Peter J. Stubbs and Louis Dellwig, indicated the presence of a 346 foot salt formation beneath the Blaine Anhydrite, at depths from 1615 feet to 1961 feet. Underlying this salt section is 100+ feet of salt-impregnated sandstone.

One hundred and sixty-one spot samples of the salt section were collected for examination in the Geochemical Laboratories of the Kansas Geological Survey. The samples, which ranged in weight from 25 to 100 grams, were crushed to minus 1/4 inch and subjected to treatment in distilled water for removal of soluble salts. X-ray diffraction analyses of the crystallized salts of selected samples indicate the soluble salts to be virtually pure halite (NaCl). However, the formation of small gypsum crystals indicates either the presence of gypsum in the original sample, or suggests a slight solubility of the anhydrite impurities present in the salt samples.

The results of the water-insoluble residue analyses are tabulated in the Appendix at the end of this chapter, and indicate the overall salt purity of the salt formation from 1620 to 1950 feet is on the order of 80%. The predominantly red insoluble impurities of this section are concentrated around salt crystal grain boundaries, and hence the small spot samples are not truly representative samples of the core. However, the results of these analyses parallel quite well the results of the visual estimates made by Louis Dellwig, and the overall trends appear to be valid. Two 30-foot zones may merit a closer examination (1622-1652' and 1820-1850'), if this test hole location meets all other requirements for a repository vault and if salt purity requirements are lowered to 90%. It should be noted, that despite the results of the analyses presented in the Appendix, the salt purity of the 30-foot section from 1820 to 1850 is not likely to exceed 95%. Difficulties in obtaining small representative samples preclude accurate sample analysis.

Petrographic observations of the original samples and the insoluble residues indicate the bulk of the impurities to be exceptionally fine-grained in nature. Most distinct mineral crystals are in the very fine to medium silt size range (4-30 microns) and are imbedded in a clay-sized matrix (less than 4 microns). Even under a magnification of 500 to 1000 x, it is extremely difficult to identify the mineralogic constituents of the insoluble material. The insoluble material very rarely exhibits any sort of textural lamination, and hence should be classified as "claystone" or "mudstone", not "shale" or "siltstone".

X-Ray Analysis

The results of x-ray diffraction analyses of selected samples are presented in Table 6. Although the insoluble impurities in the salt section have a very uniform appearance, i.e., red claystone or white to pinkish anhydrite, the difration analyses revealed the rather prominent presence of dolomite (Ca-Mg carbonate) and magnesite (Mg-carbonate), as well as suggesting a unique suite of clay minerals: illite and swelling chlorite.

Since one x-ray pattern is not sufficient to identify clay minerals with expanding lattice properties, two samples (1617.5' and 1814.8') were subjected to more detailed chemical and x-ray analyses. The removal of soluble salts, carbonates, iron-oxide coatings and exchangeable cations was accomplished by a pH 5 NaOAc acid leach, sodium citrate-dithionite-bicarbonate iron removal, and a pH 9.5 $NaCO_3$ dispersal procedure, followed by various cation saturations and the preparation of oriented unsized sedimented slides from clay-ethanol slurries. Diffraction patterns were run on air dried (60%

Table 6.--Mineralogy of Water-Insoluble Residues from AEC Test Hole 5.

M = magnesite $MgCO_3$
D = dolomite $(Ca,Mg)CO_3$
A = anhydrite $CaSO_4$
Q = quartz SiO_2
C-V = chlorite-vermiculite (?)
I = illite
F = hematite Fe_2O_3 and/or goethite $Fe_2O_3 \cdot H_2O$

Insol. wt. %	Sample Footage	Major (25-100%)	Minor (5-25%)	Trace (1-5%)
50	1617.5	M	C-V,I	F
30	1618.8	C-V,I	Q	F
19	1620.8	M	C-V,I	F
6	1624.8	A		
31	1626.7	A		
10	1628.8	M	C-V,I	F
13	1632.8	A,M	C-V,I	F
8	1636.8	D,A	C-V,I	F
19	1640.8	C-V,A	M	I,F
4	1644.8	C-V,I		F
1	1648.7	M	C-V,I	F
13	1650.8	A		
23	1654.8	M		C-V,I,A,F
10	1658.8	C-V,I	Q	F
13	1662.8		Q,A,C-V,I	F
2	1666.8	A		C-V,I,Q,F
50	1672.8	A		C-V,I,Q
73	1676.8	A		
88	1678.8	A,M	C-V,I	F
4	1680.8		D,C-V,I,Q	F
75	1710.8	D	C-V,I	F
68	1788.8		A,Q,C-V,I	F
81	1814.8		A,Q,C-V,I	F
75	1850.6	C-V,I,Q		F
61	1938.8	D	C-V,I	Q,F

humidity) and glycolated slides as well as a heat treated slides (110°, 300°, 400°, 450°, 500°, and 600° C) that were dessicator cooled. Some heat-treated slides were also allowed to rehydrate in air with 60% humidity. The results of these analyses indicate a swelling chlorite with minor amounts of illite. The presence of an expanding-lattice clay mineral in these samples is of particular significance, as this material has the ability to gain or lose interlayer water, i.e., expand or contract with variations in temperature and/or humidity. This property may exert a considerable influence of the design of a repository vault, as the clay could "pop" salt crystals out of ceiling-wall areas, especially as heating occurs and interlayer water is ejected.

In conclusion, the results of this study indicate that (1) two 30-foot sections have a 90 to 95% salt purity, (2) heat flow calculations should take into account the presence of $MgCO_3$ and $(Ca,Mg)CO_3$, as well as anhydrite and layer-silicates and (3) mining and mine-life problems should consider the mineralogy of the salt impurities, particularly expanding lattice layer silicates.

APPENDIX

Insoluble Residue Analyses

AEC 5 Salt Formation

Spot samples (25-100 gm) collected by D. Brinkley.

Footage	Insol. wt. %	Footage	Insol. wt. %	Footage	Insol. wt. %
1617.5	50	1706.8	3	1782.8	2
1618.8	30	1708.8	7	1784.8	11
1620.8	19	1710.8	75	1786.7	6
1622.8	1	1712.8	4	1788.8	68
1624.8	6	1714.9	7	1790.7	57
1626.7	31	1716.8	7	1792.8	18
1628.8	10	1718.8	16	1794.8	2
1630.8	11	1720.8	13	1796.7	29
1632.8	13	1722.8	59	1798.8	2
1634.8	19	1724.8	15	1800.8	11
1636.8	8	1726.8	6	1802.8	7
1638.9	10	1728.8	12	1804.7	4
1640.8	19	1730.8	9	1806.8	2
1642.8	3	1732.8	9	1808.8	3
1644.8	4	1734.6	4	1810.8	16
1646.8	1	1736.8	9	1812.5	10
1648.7	1	1738.7	7	1814.8	81
1650.8	13	1740.7	26	1816.8	8
1652.8	10	1743.0	43	1818.8	9
1654.8	23	1744.8	16	1820.8	2
1656.7	4	1746.8	13	1822.8	8
1658.8	16	1748.8	43	1824.8	3
1660.8	1	1750.7	3	1826.8	5
1662.8	13	1752.8	3	1828.8	3
1664.8	1	1754.8	6	1830.8	6
1666.8	2	1756.7	22	1833.1	4
1668.7	2	1758.7	6	1834.9	1
1670.8	1	1760.7	10	1836.7	1
1672.8	50	1762.8	6	1838.8	8
1674.8	70	1764.8	1	1841.1	3
1676.8	73	1766.3	1	1842.8	8
1678.8	88	1768.9	6	1844.9	9
1680.8	4	1770.8	10	1846.8	4
1682.8	16	1772.8	5	1848.8	4
1684.8	1	1774.9	3	1850.6	75
1686.8	1	1776.7	13	1852.8	23
1688.8	1	1778.7	54	1854.8	27
1704.8	7	1780.8	4	1856.8	6

Footage	Insol. wt. %
1858.9	3
1860.8	58
1862.8	39
1864.6	4
1866.8	3
1868.5	8
1870.8	16
1872.8	14
1874.8	4
1876.8	18
1878.8	4
1880.8	4
1882.8	9
1884.8	12
1886.8	7
1889.1	17
1890.8	3
1892.8	10
1894.8	14
1896.8	12
1898.8	7
1900.8	7
1902.8	1
1904.8	26
1906.8	13
1909.8	1
1910.8	27
1912.8	8
1914.6	27
1916.7	8
1918.8	6
1920.8	16
1922.7	4
1924.8	10
1926.8	14
1928.8	21
1930.8	4
1932.8	32
1934.8	6
1936.8	29
1938.8	61
1940.8	35
1942.8	31
1944.8	20
1946.8	16
1948.8	63
1950.8	13
1952.8	74
1954.6	69
1956.7	34
1958.9	34
1960.8	6
1962.8	78
1964.8	84
1966.8	86
1968.8	63
1980.0	74
1990.0	67
2000.0	67
2010.0	70
2020.0	72
2030.0	77

Chapter 7

SUMMARY AND CONCLUSIONS

by

Charles K. Bayne and John C. Halepaska

Certain criteria must be considered in determining the suitability of a site for use as a radioactive waste respoitory. Criteria believed favorable to the use of a site for storage of wastes are considered when selecting a site for additional study. It is generally after additional study of an area that negative or unfavorable factors may become apparent which may eliminate that site from further consideration.

The criteria considered by Angino et al. (1972) are based primarily upon safety factors, and are used for comparison of data in this report. Criteria considered by ORNL document of March 1, 1972 are based on factors concerned with safety but also, in part, on economic factors concerned with construction and operation of a waste repository.

Some criteria considered in the suitability of AEC sites 3, 4, and 5 and a comparison with the Lyons site are given in Table 5. No consideration is given to the importance of one factor over another; however, certain factors are prerequisite to the consideration of any site. Among these are salt thickness and quality, adequate buffer zones for safety of people, water above and below the salt and drill holes which may be a means of water entering the repository.

Table 7.--Factors and ORNL Criteria Considered for Suitability for Waste Repository Sites AEC 3, 4, 5 and Lyons (AEC 1).

	AEC 3	AEC 4	AEC 5	Lyons (AEC 1)	ORNL Criteria
Salt Thickness (feet) (1)	157	166	346	266	> 200
Depth to top of salt (feet)	816	1021	1615	815	> 700
Depth to base of salt (feet)	973	1187	1961	1081	
Number of Drill Holes (2 miles) Penetrating salt	0	0	0	95 (2)	minimum number
Number of Drill Holes (5 miles) Penetrating salt	3	3	3	360 (3)	
Water (quantity and quality)	1 or 2	2 or 1	3 (4)	4 (5)	< 50 gpm
Distances from population centers	10 miles	5 miles	6 miles	Not adequate	2-5 mi.
Railroad Trans.	12 mi. from mainline	6 mi. from branchline	7 mi. from mainline	branchline adjacent	
Highway Trans.	I-70 2.5 mi., K-14 1 mi.	K-18 4 mi.	K-25 1 mi.	U.S. 56 1 mi., K-14 1 mi.	
Salt Disposal (6)	2	3	4	1	
Potential Vault Zones (7)	0-1	0	0	1	> 12 ft > 95%

(1) Salt from Lyons, AEC 3 and AEC 4 are of nearly equal quality. Salt from AEC 5 is of poor quality because of presence of red clay inclusions.
(2) Ten drilled holes are inside the 1000-acre site and 2 shafts.
(3) Number refers to recorded drill holes. Drilling began in 1888 and records have been required since 1935.
(4) Permeable zone 45 feet above salt.
(5) Poor rating because of unexplained pressure sink in SE corner of area.
(6) Based on geographic location from possible disposal sites.
(7) Based on a sufficiently thick interval of high quality salt.

In AEC 3 the salt is at the shallowest depth but the salt section is also thinnest at this site. Except for AEC 3 test hole, which was drilled in the northeast corner of the site, no drill holes penetrate the salt within a 2-mile radius of the site, and only three drill holes within a 5-mile radius. The Permian rocks above and below the salt are of very low permeability and would yield little or no water to wells. In the Cretaceous rocks somewhat more water is available at this site than at AEC 4 or 5. This water is generally of fair to good quality. AEC 3 is located about 10 miles from Lincoln and Ellsworth and is 12 miles from the mainline of the Union Pacific Railroad. This area is the nearest of the three sites to possible disposal sites for excess salt. The site contains one zone of marginal thickness and quality of salt for a vault zone.

In AEC 4 the top of the salt is at a depth about 200 feet deeper and 10 feet thicker than in AEC 3. AEC 4 was drilled adjacent to the site and no other drill holes are present within a 2-mile radius and only three holes are within the 5-mile radius. Permian rocks above and below the salt have a very low permeability and would yield little or no water to wells. In the Cretaceous rocks somewhat less water is available than at AEC 3 but more than is available at AEC 5. The water in this area is generally of poor quality. The area is 5 miles from Lucas and 6 miles from Sylvan Grove and is located about 6 miles from a branchline of the Union Pacific Railroad. The area is about 30 miles more distant from possible disposal sites of excess salt than AEC 3. This area has insufficient thickness and quality of salt for a vault zone.

The top of the salt in AEC 5 is about 600 feet deeper than the top of the salt of AEC 4 and about 800 feet deeper than at AEC 3. The thickness of the salt section at AEC 5 meets ORNL criteria for thickness but fails to meet quality criteria. The salt in AEC 5 is generally not bedded salt and has fine red clay inclusions and coatings on crystal faces which might cause weakness in pillars and the roof of a mine. Except for AEC 5 which was drilled adjacent to the northwest corner of the site, no drill holes are within a 2-mile radius of the site and 3 holes within the 5-mile radius. Hydraulic testing below the salt indicates a very low permeability for this section of rocks. In the Permian rocks above the salt hydraulic tests indicate a zone capable of yielding some water to wells. Hydraulic tests on the Dakota Formation were inconclusive. The Dakota in this area may have a relatively low permeability and capable of yielding only small quantities of water to wells. The Ogallala Formation at the site should be capable of yielding about 100 gpm to wells in this area. This area is 6 miles from Leoti and is about 7 miles from the mainline of the Missouri Pacific Railroad. This area is the most remote from possible disposal sites. Because of the lack of bedding and clay inclusions within and around salt crystals no vault zones are considered to be present.

In conclusion Areas A, A-1 and D-2 fail to meet detailed criteria as stated by ORNL document, March 1, 1972.

Specifically Area A (AEC 3) and Area A-1 (AEC 4) fail to meet the criteria concerning thickness and quality. Area D-2 (AEC 5) fails to meet the criteria concerning quality and mineability of the salt. In addition the Lyons site fails to meet either sets of criteria in that there are many drill holes both within the site and in adjacent areas; the unanswered question concerning the piezometric low in the southeast part of the site and has an inadequate buffer zone. In Angino et al. (1972) Areas A, A-1 and D-2 meet most of the stated criteria.

Areas west of Area A-1 (AEC 4) and in south-central Harper County, in our opinion, appear to be the best prospects for future study in Kansas. See Area 1 and Area 5 in Angino et al. (1972).

REFERENCES

Angino, Ernest E., Bayne, Charles, K., and Halepaska John, 1972, Preliminary Geological Investigations of Supplemental Radioactive Waste Repository Areas in the State of Kansas. State Geological Survey of Kansas, 95 pp.

Angino, E. E. and Hambleton, W. W., 1971, Geology and Hydrology of the Proposed Lyons, Kansas, Radioactive Waste Repository Site. (Final Report). State Geological Survey of Kansas. 190 pp.

Oak Ridge National Laboratory, 1972, Federal Waste Repository: Site Selection Factors and Criteria. ORNL Central file no. 72-3-4.