Kansas Department of Health
& Environment
Bureau of Water
Geology Section

1000 SW Jackson St. Suite 420
Topeka, Kansas
66612-1367

April 2009
www.kdheks.gov/geo

2008 KDHE OVERVIEW OF THE UIC PROGRAM ADDRESSING CLASS III INJECTION WELLS

AN OVERVIEW OF THE KDHE UIC PROGRAM ADDRESSING CLASS III INJECTION WELLS

INTRODUCTION

Bedded salt deposits in Central Kansas have been mined for many years by solution mining methods. Historical records indicate solution mining methods for the extraction of brine has occurred in Kansas since the 1880's.

When fresh water or weak brine is injected into a solution mining well (Class III), the water contacts the salt deposits, dissolves the salt, and brine is then brought to the surface for evaporation or other uses at salt or chemical plants. Contamination of groundwater supplies and soils can result from the failure to install adequate well casing for protection of the fresh and usable water zones; the operation of wells with adequate salt roof thickness which can cause surface subsidence or collapse; or the improper maintenance of surface piping and valves.

After several cavern collapses and subsidences of solution mining wells in the late 1970's in Kansas, the Kansas Department of Health and Environment (KDHE) promulgated regulations governing salt solution mining wells in 1979. Kansas Administrative Regulations (K.A.R.) 28-43-1 through 28-43-11 (Article 43) govern salt solution mining wells in Kansas. These regulations address the permitting, construction, monitoring and plugging of salt solution mining wells.

Nationally, a number of pollution incidents were traced to the use of injection wells. It was then realized that injection activities could contaminate groundwater if not conducted under strict controls. This realization prompted Congress to develop the Federal Underground Injection Control (UIC) program as part of the Safe Drinking Water Act (SDWA) of 1974. As stated previously, the State of Kansas has regulated salt solution mining wells since the late 1970's. The Environmental Protection Agency (EPA) has delegated primary regulatory authority for the federal program to those states agencies that have demonstrated an ability to implement a UIC program that meets EPA requirements promulgated under the SDWA. These states are referred to as Primacy States. The KDHE received primacy from EPA in December, 1983, to administer the Federal UIC program in Kansas for Class I, III, IV and V wells. Kansas Administrative Regulations 28-46-1 through 28-46-44 govern these classes of UIC wells in Kansas in addition to the Article 43 regulations for Class III injection wells.

The purpose of the UIC program is to prevent contamination of fresh and usable groundwater supplies by injection activities. In Kansas, approximately 90% of the water used is supplied from groundwater. The major contamination problems in Kansas are from sources associated with human activity. The groundwater supply can be lost for use if not adequately protected from contamination. The most effective method of protecting groundwater supplies is to prevent contamination. Prevention is much more cost effective, and has better results than cleanup activities.

This document has been printed for use only as an overview of that part of the KDHE UIC program addressing Class III injection wells. It is not intended to be an all inclusive listing of requirements or conditions for Class III injection wells. This document may not be used in a court of law. Many of the requirements listed have been taken from the official Kansas Administrative Regulations publication. The permit application, permits, policies, guidances, statutes and rules and regulations establish the specific requirements for Class III injection wells and are available from KDHE.

DEFINITIONS

A well means a dug hole or bored, drilled or driven shaft whose depth is greater than its largest surface dimension or an improved sinkhole, or a subsurface fluid distribution system.

Well Injection means the subsurface emplacement of fluids through a well.

Injection well is a well into which fluids are injected.

A fluid is defined as any material that flows or moves, whether it is semi-solid, liquid, sludge or gas.

As mentioned previously, the UIC program categorizes injection wells into five classes of wells. These are:

Class I : Wells used to inject hazardous wastes or dispose of industrial and municipal fluids beneath the lower formation containing, within one quarter (1/4) mile of the wellbore, a source of fresh or usable water.

Class II: Wells used to inject fluids associated with the production of oil and natural gas or fluids/compounds used for enhanced hydrocarbon recovery. These wells normally inject below the lower-most fresh or usable water bearing zone except in cases where this zone is hydrocarbon producing.

Class III: Wells which inject fluids for the extraction of minerals.

Class IV: Wells which dispose of hazardous or radioactive wastes into or above a fresh or usable water bearing zone. **Class IV wells are prohibited.**

Class V: Wells not included in other classes. Typically Class V injection wells are shallow wells used to place a variety of fluids below the land surface.

Injection into a Class I, III and certain types of Class V wells requires obtaining a permit from KDHE prior to construction. As stated previously, injection into a Class II well requires obtaining a permit from the Kansas Corporation Commission.

The subject of this document is that part of KDHE's UIC program addressing Class III salt solution mining wells.

INVENTORY

The number of Class III wells currently on the KDHE inventory as of January 1, 2007 are shown in Table 1. The inventory includes active wells, wells permitted but not yet constructed, and plugged and abandoned wells.

TABLE I.
CLASS III WELL INVENTORY
Number of Wells as of January 1, 2009

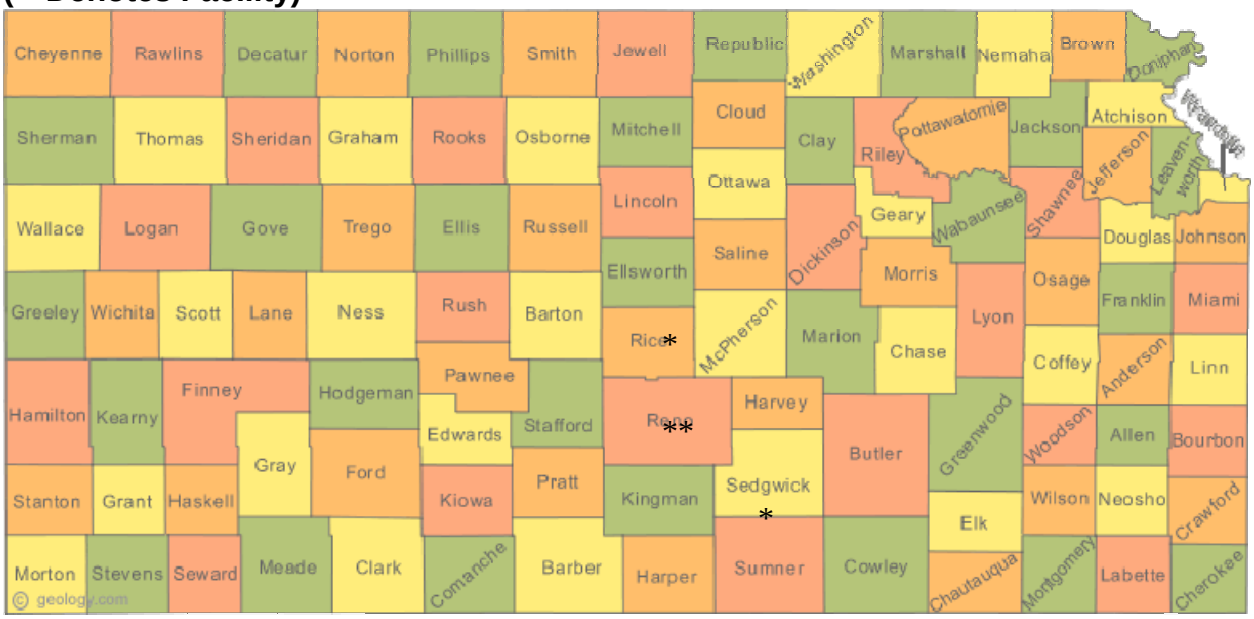
Active	Permitted – Not Constructed	Plugged	Abandoned*	Total
140	0	524	6	670

* The majority of abandoned wells are wells that have subsided or collapsed.

LOCATION OF CLASS III INJECTION WELL FACILITIES

There are currently four salt production facilities located in Kansas which utilize a total of 140 active Class III wells for the solution mining of salt. The location of these facilities is indicated in Figure 1.

Figure 1 – CLASS III FACILITIES
(*- Denotes Facility)



DESCRIPTION OF HUTCHINSON SALT DEPOSIT IN KANSAS

The salt which is solution mined in Kansas is the Hutchinson Salt member of the Wellington formation and is of Permian age. The Hutchinson Salt is a layered salt formation consisting of halite and “dirty” halite beds separated by shale beds, shale partings, thin anhydrite layers and thin limestone layers. On average, the Hutchinson Salt consists of 80% halite, 5% calcium sulfate, 5% carbonate and 10% shale. The Hutchinson Salt varies in thickness from a few feet to 400 feet. Where solution mining is conducted in Kansas, the average thickness is approximately 375 feet. The depth to the top of the Hutchinson Salt, in areas where solution mining takes place, varies from approximately 225 feet to 725 feet below ground surface. The depositional environment of the Hutchinson Salt is described as a broad, shallow embayment with extensive tidal flats. The salt beds are nearly horizontal with a westerly regional dip of approximately 30 feet/mile.

The Hutchinson Salt is overlain by shale beds of the Wellington formation. These Wellington shale deposits are nearly impermeable and serve to separate the salt beds from the unconsolidated sand and gravel aquifers which overlie the shale.

DESCRIPTION OF SALT SOLUTION MINING ACTIVITY

Salt solution mining is accomplished using either single well or gallery system designs. For each solution mining well, surface casing is set through all fresh and usable water formations (water <10,000 mg/L Total Dissolve Solids) and encased to the surface. The production casing is then set at least 45 feet in the top of the salt formation and cemented from the bottom of the casing to surface. The requirement to set the casing 45 feet into the salt formation is to ensure the existence of a 40 foot salt roof in the wells.

In single well systems, mining occurs by injection of fresh or unsaturated water down injection tubing. When the fresh water contacts the salt, solutioning occurs and a cavern begins to form. Saturated brine is then withdrawn from the well through the casing/tubing annulus. Figure 10 depicts a typical Class III well.

Gallery systems are usually designed with groups of five or more wells. The cavities of the wells are interconnected so injection or brine production can occur throughout different wells. Some systems are developed as “five-or six-spots” where a center well is surrounded by four or five perimeter wells. These wells are connected by hydrofracing and mining occurs by injection of fresh water into the perimeter wells and withdrawal of brine from the center well. Hydrofracing is accomplished by injection of water into newly completed wells using pressures which fracture the salt. As the fracture propagates, it intersects the boreholes of other wells in the gallery and the gallery is then connected. Hydrofracing is not an exact science and there have been incidents where a connection has not occurred between all wells in a gallery or where the fracture has traveled in all directions away from the target wells. When all wells in a gallery do not connect, the mining capacity of the gallery is reduced. If uncontrolled fractures travel and intersect abandoned or active boreholes, fluid can flow at the

surface and remedial work may be needed on the wells. Figure 11 depicts a typical five spot gallery.

Since there have been problems with hydrofracing over the years, another design of gallery systems was introduced by industry about 10 years ago. These "horizontal well galleries" are developed by drilling a horizontal borehole along the base of the salt section and then constructing vertical wells which will come close to, or may intersect, the horizontal borehole. The vertical and horizontal wells are washed until connection occurs. Mining can then begin. With this type of gallery, connection of the gallery wells is more probable and controlled. Also, the development of the cavities can be controlled by alternating between injection and withdrawal modes of wells in the gallery. Figure 12 depicts a typical horizontal well gallery.

Class III salt solution mining wells are used at two different types of facilities in Kansas. Three facilities use the brine from these wells for production of such items as: food grade salt; salt for pharmaceutical products; salt blocks for livestock; and water softener pellets. One chemical manufacturing facility uses the brine as a chlorine feed stock for use in production of various chemicals, including chlorinated hydrocarbon chemicals. A total of 2,071,506,900 gallons of brine were safely produced in 2008.

SIGNIFICANT REQUIREMENTS

DESCRIPTION

This section lists only the more significant requirements for Class III salt solution mining wells and is intended to give only an overview. This is not an all inclusive listing of requirements. The permit application, permits, policies, statutes and rules and regulations establish the specific requirements for Class III salt solution mining wells.

A. Permitting Requirements

A Class III injection well shall not be constructed, and underground injection shall not take place, unless authorized by a permit issued by the KDHE, Bureau of Water (K.A.R. 28-46-25 and K.A.R. 28-43-3). A permit application can be obtained by contacting KDHE.

B. Construction Requirements

The well shall be cased and cemented such that: 1) injected and withdrawn fluids do not cause deterioration of the water quality of fresh and/or usable water zones, 2) the loss of fresh and/or usable water due to downward migration is prevented, 3) the release of injected or withdrawn fluids into an unauthorized zone is prevented, and 4) appropriate testing devices and workover tools can be used.

- The casing and cement used in the construction of the well shall be designed for the life expectancy of the well. (K.A.R. 28-46-29).

- New surface casing shall be set and cemented through all fresh and usable water zones and any other zones determined necessary by KDHE. (K.A.R. 28-46-9, K.A.R. 28-46-29 and K.A.R. 28-43-5)

- New production casing shall be set at least 45 feet into the upper part of the salt formation to ensure the existence of a salt roof having a thickness of at least 40 feet above the washed cavern. The production string casing shall be cemented from bottom to surface. The cement used for cementing the casing opposite the salt formation shall be prepared with salt saturated cement. (K.A.R. 28-46-9, K.A.R. 28-46-29 and K.A.R. 28-43-5).

- Salt solution mining wells shall be located not less than 300 feet from other active or abandoned brine wells or other holes or excavations penetrating the salt section, except where such wells, holes or excavations have been properly plugged. (K.A.R. 28-43-5).

- Salt solution mining wells shall be located not less than 150 feet from existing surface structures, including any transportation artery. In addition, the salt solution mining wells shall be located not less than 150 feet from the boundary of the tract(s) of land in, upon or under which the operator has the right to solution mine salt. (K.A.R. 28-43-5)

C. <u>Operational Requirements</u>

The well shall be operated in a manner that does not endanger public health or the environment.

- Except during initial well stimulation for development of salt solution mining galleries, the maximum injection pressure shall not exceed fracture pressure and shall not initiate new fractures or propagate existing fractures in the injection zone. (K.A.R. 28-46-9, K.A.R. 28-46-28 and K.A.R. 28-46-30)

- The well shall not be operated in a manner that allows the movement of fluids containing any contaminant into underground sources of drinking water. (K.A.R. 28-46-27)

- Brine shall not be produced from a salt solution mining well where the salt roof is less than 40 feet in thickness above the washed cavern. (K.A.R. 28-43-5 and K.A.R. 28-46-9)

- Brine shall not be produced from a single well where the cavern exceeds 300 feet in horizontal diameter. (K.A.R. 28-43-5)

- Where a solution cavern has been developed as part of a gallery system, brine shall not be produced from a well if the dimensions of the cavern across a horizontal plane, other than the dimensions that include an adjacent cavern within the system, exceed 400 feet at any depth or 300 feet in the upper one-third of potential cavern height. (K.A.R. 28-43-5).

- In areas of Kansas where the depth to the top of the salt section is less than 400 feet below land surface, all horizontal dimensions, except the route of interconnection between wells, shall not exceed 300 feet in diameter. (K.A.R. 28-43-5)

D. Monitoring and Reporting Requirements

- Samples and measurements taken for the purpose of monitoring shall be representative of the activity being monitored. (K.A.R. 28-46-6, K.A.R. 28-46-9 and K.A.R. 28-46-30)

- All analyses of the injected and withdrawn liquid required by the permit shall be conducted by a Kansas Certified laboratory. (K.A.R. 28-46-43)

- The injected fluid shall be analyzed with sufficient frequency to yield representative data of the characteristics. (K.A.R. 28-46-9 and 28-46-30)

- The injected and withdrawn liquid volume shall be metered continuously and the volume recorded weekly for each well or well system. (K.A.R. 28-46-9, K.A.R. 28-46-30 and K.A.R. 28-43-7)

- The minimum and maximum injection pressures shall be measured continuously and recorded weekly for each well or well system. (K.A.R. 28-46-9, K.A.R. 28-46-30 and K.A.R. 28-43-7)

- An annual report of salt solution mining activity shall be submitted and shall be submitted and shall include discussion of activities on drilling, plugging, gamma logging, sonar caliper surveys, mechanical integrity testing and an estimate of the percent of useful life remaining for each well. (K.A.R. 28-46-9, K.A.R. 28-46-12 and K.A.R. 28-46-30)

- A quarterly monitoring report using a form approved by KDHE shall be submitted to KDHE no later than 28 days after the last day of the quarter for which the monitoring data are being reported. (K.A.R. 28-46-9, K.A.R. 28-46-12 and K.A.R. 28-46-30)

- A quarterly monitoring report shall include all data required by the permit. At a minimum, this shall include the injected and withdrawn volume (recorded weekly); and calculations of the withdrawal/injection ratio. (K.A.R. 28-46-9 and K.A.R. 28-46-30)

- When calculations indicate that 50% of the useful life of the well has been reached, the well shall be checked to determine the dimensions of the cavern. The dimensions shall be determined thereafter upon increments of each 10% of useful well life. A sonar caliper survey shall be used for this purpose. The results shall be submitted to KDHE within 30 days of test completion. (K.A.R. 28-46-9 and K.A.R. 28-43-7)

- The thickness of the salt roof shall be determined at least once every two years by conducting an expanded gamma ray log or other KDHE approved log. The results shall be submitted to KDHE within 30 days of test completion. (K.A.R. 28-46-9 and K.A.R. 28-43-7)

- The surface elevation of the wellhead shall be determined annually. The results shall be submitted to KDHE within 30 days of completion. (K.A.R. 28-46-9 and K.A.R. 28-43-7)

E. Mechanical Integrity

It is necessary to periodically test the injection well components to demonstrate there is no significant leak in the well components (internal mechanical integrity) and to review cement tickets and cement bond logs to demonstrate no significant fluid movement is occurring through vertical channels adjacent to the well bore (external mechanical integrity) The test shall also be conducted when KDHE believes continued use of the well constitutes a threat to human health or the environment. When there is no significant leakage in the well components the well is said to have mechanical integrity.

There are two separate parts of mechanical integrity. Part 1 mechanical integrity is demonstrated when there is no significant leak in the casing. Part 2 is satisfied when there is no significant fluid movement through vertical channels adjacent to the borehole.

A mechanical integrity test (MIT) plan and schedule shall be submitted to KDHE for review and approval prior to conducting an MIT. No testing shall commence until plan approval has been obtained from KDHE (K.A.R. 28-46-9). Specific guidelines for developing an MIT plan and for test procedures can be obtained by contacting KDHE.

Significant requirements for mechanical integrity are as follows:

Part 1 Mechanical Integrity

- A hydraulic pressure test of the casing by using a mechanical packer or retrievable plug shall be conducted at least once every five years. (K.A.R. 28-46-33)

- The test pressure must be a minimum of 150 psig or 1.5 times the operating pressure at the wellhead, whichever is greater, and the test must be at least one hour in duration. A pressure loss equal to or less than 5% of the original test pressure is a satisfactory test. A pressure increase greater than 5% is unacceptable and may indicate the well is not in thermal equilibrium. (K.A.R. 28-46-33)

Part 2 Mechanical Integrity

- The review of cementing records and cement bond logs for the production string casing shall be conducted upon completion of a new well and when permits are due for reissuance. (K.A.R. 28-46-33)

F. Plugging and Closure

At the end of the useful life of the well or when determined necessary by KDHE to protect human health or the environment, the well shall be properly plugged or closed. The well shall be plugged in a manner that is protective of human health and the environment. A plan for plugging the well shall be maintained on file with KDHE. Prior to commencing plugging, an updated plugging plan shall be submitted to KDHE for review and approval. No plugging work shall commence until plan approval has been obtained from KDHE. Detailed guidelines and requirements for developing a plugging plan and for procedures can be obtained by contacting KDHE. A diagram of a typical plugged class III well is included as Figure 13.

Significant requirements are as follows:

- A mechanical integrity test shall be conducted on the well prior to plugging to determine the presence of any problems that might affect the plugging or closure operation and to determine the need for remediation. (K.A.R. 28-46-34)

- The tubing shall be removed from the well. (K.A.R. 28-46-34 and K.A.R. 28-43-8)

- The cavern shall be filled with brine. (K.A.R. 28-46-34 and K.A.R. 28-43-8)

- A gamma ray log, cement bond log, sonar caliper survey and other logs determined necessary by KDHE shall be conducted to determine the position of cavern roof and the salt top and to determine the need for remedial cementing before commencing the plugging operation.

- A mechanical bridge plug shall be set as near to the base of the production casing as feasible. (K.A.R. 28-46-34 and K.A.R. 28-43-8)

- The casing shall be filled with cement. (K.A.R. 28-46-34 and K.A.R. 28-43-8)

- Leave some casing above ground surface. Weld a metal plate on the casing inscribed with the Kansas UIC permit number and the date the well was plugged. (K.A.R. 28-43-8)

- Submit a map showing the tricoordinate location of the remaining wellhead prepared by a licensed professional land surveyor or professional engineer licensed to practice in Kansas. (K.A.R. 28-43-8).

- Submit a plugging report with related details to KDHE within 30 days of completing the plugging operations on a form provided by KDHE. Document the

work done with appropriate service company cementing reports and “day” reports. (K.A.R. 28-46-9, K.A.R. 28-46-34 and K.A.R. 28-43-8)

Figure 2 is composite stratigraphic section of rocks present in Kansas. Beds older than Mississipian are known only in the subsurface (modified from Moore and others, 1952).

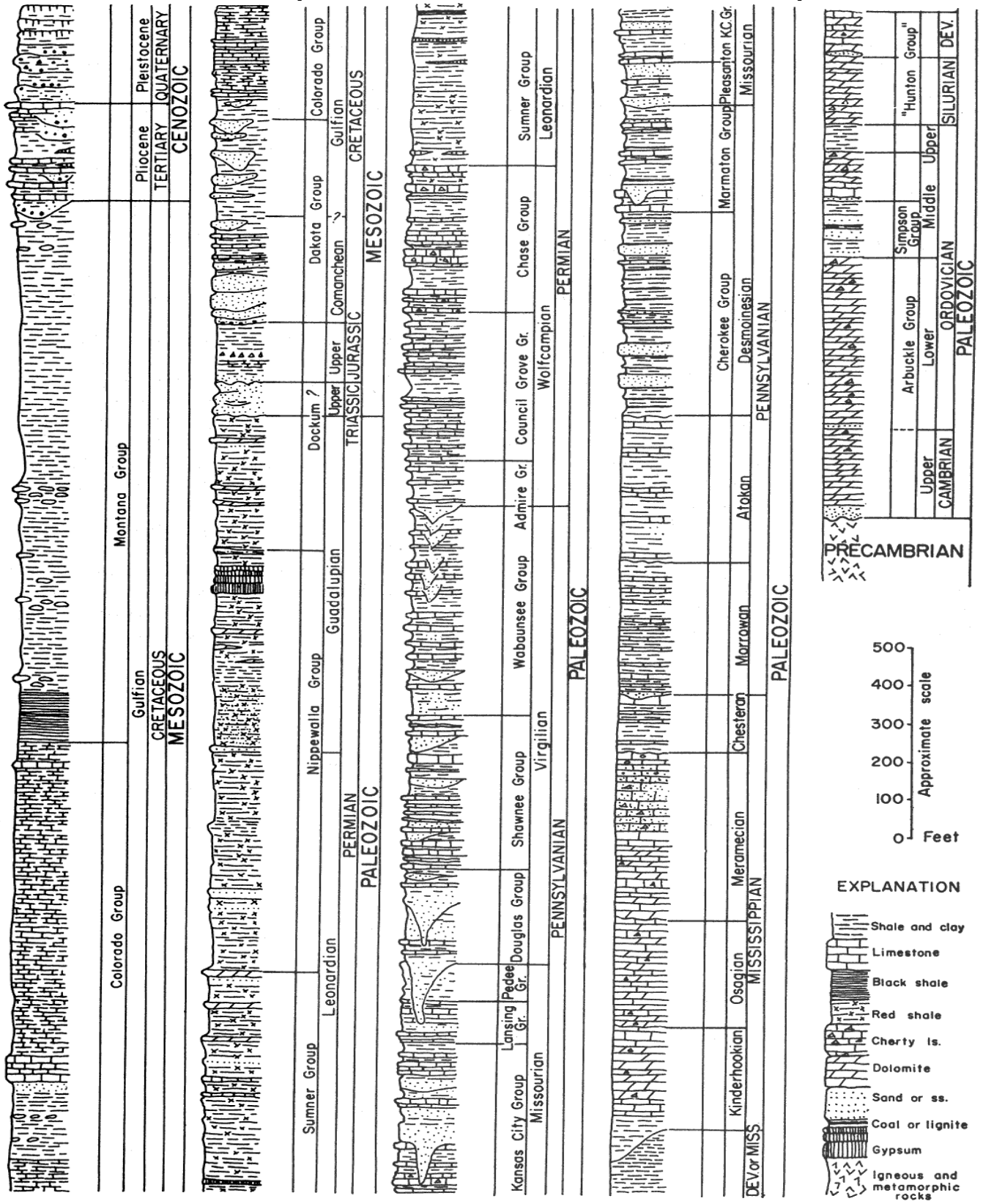


Figure 3 is a stratigraphic section showing the Hutchinson Salt member of the Permian series (source: "The Kansas Rock Column 1951).

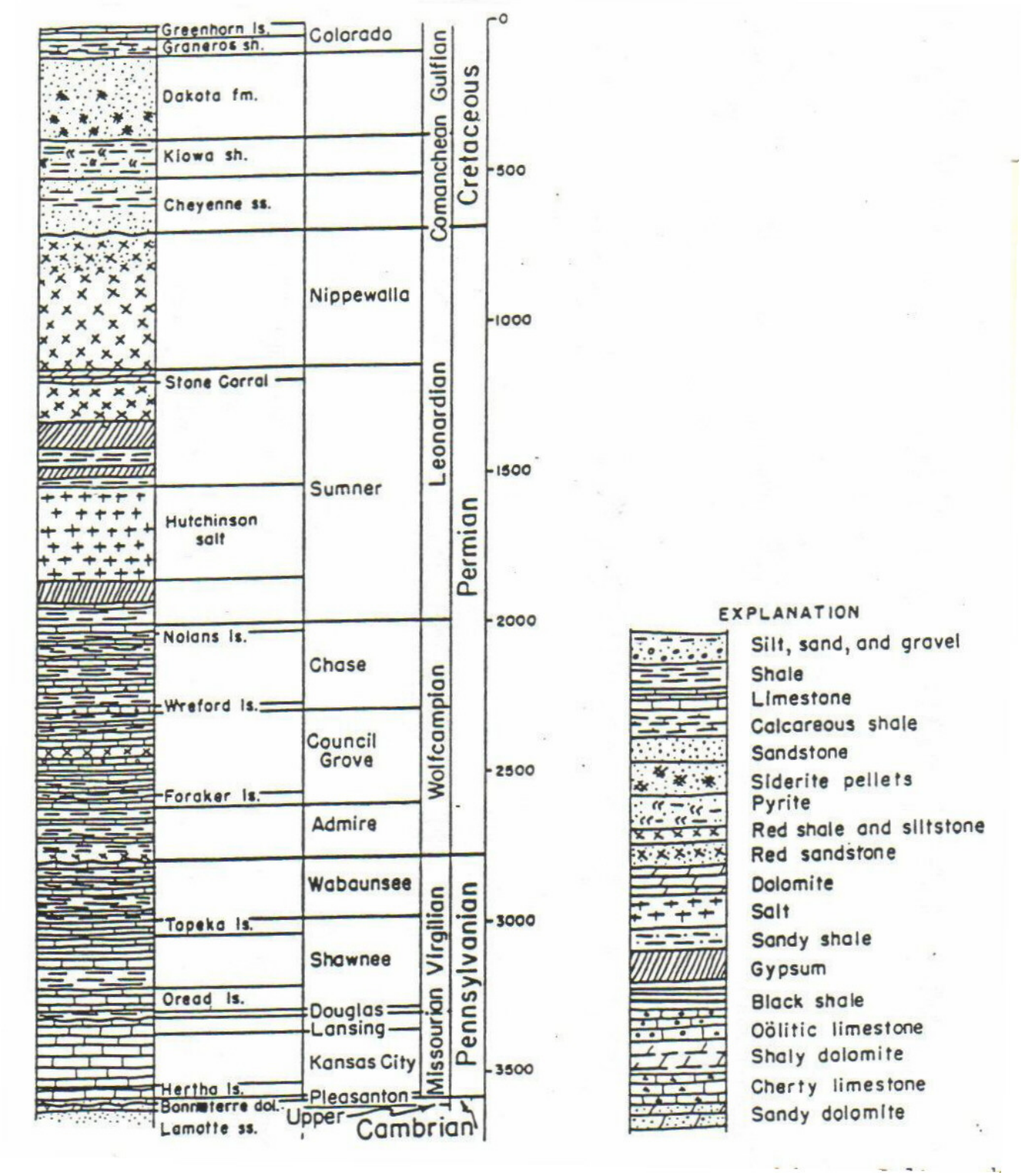
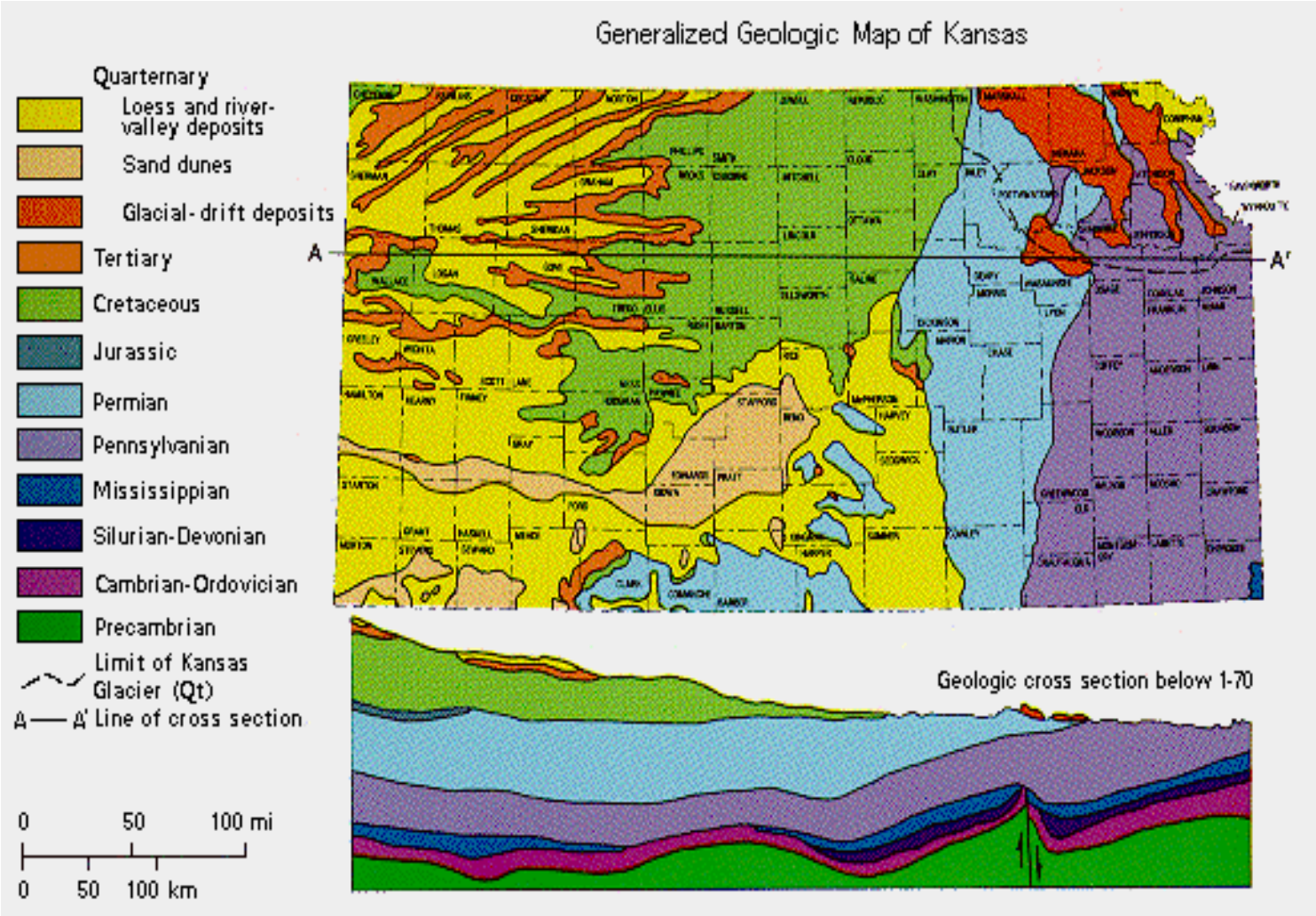
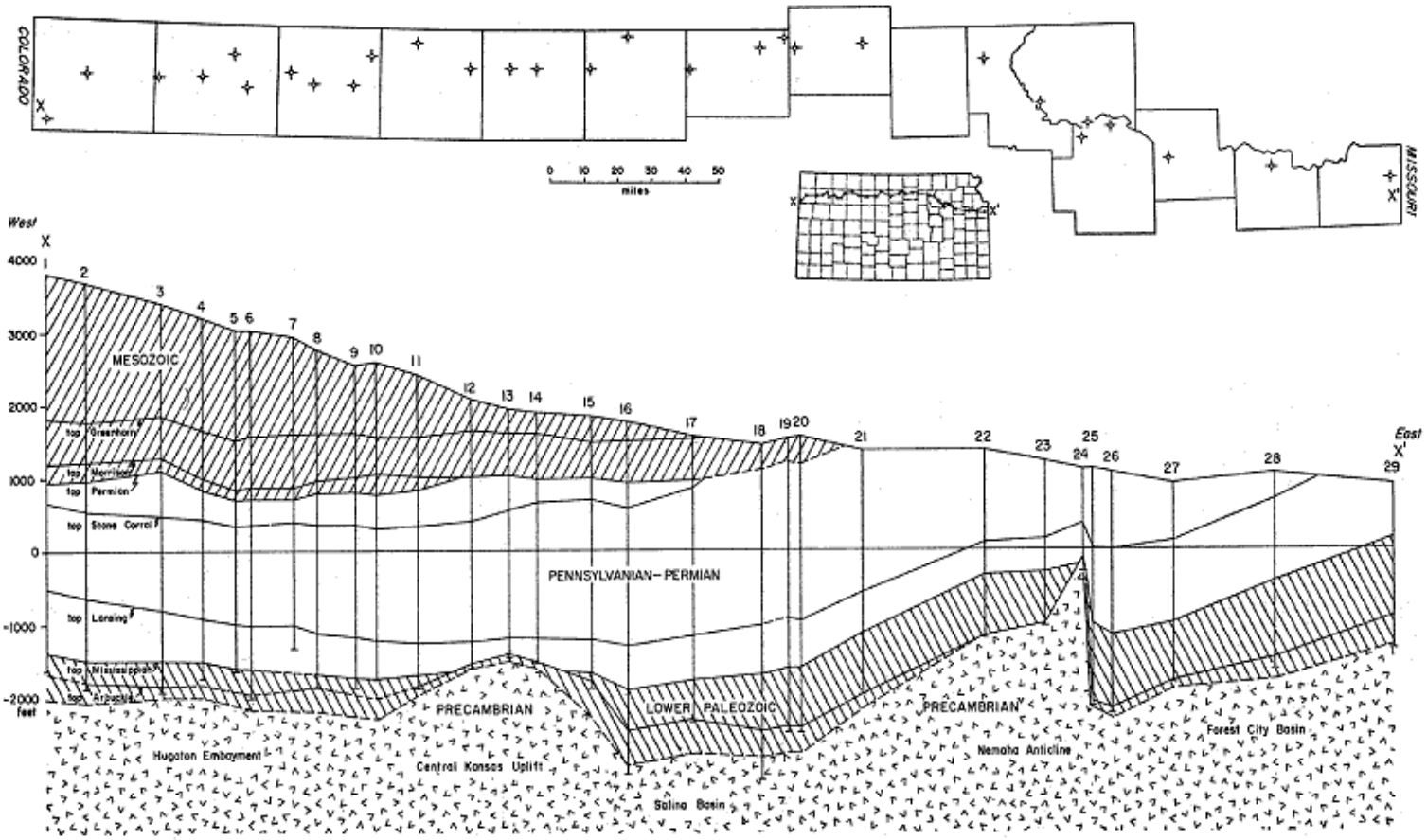


Figure 4 is a generalized geologic map of Kansas.



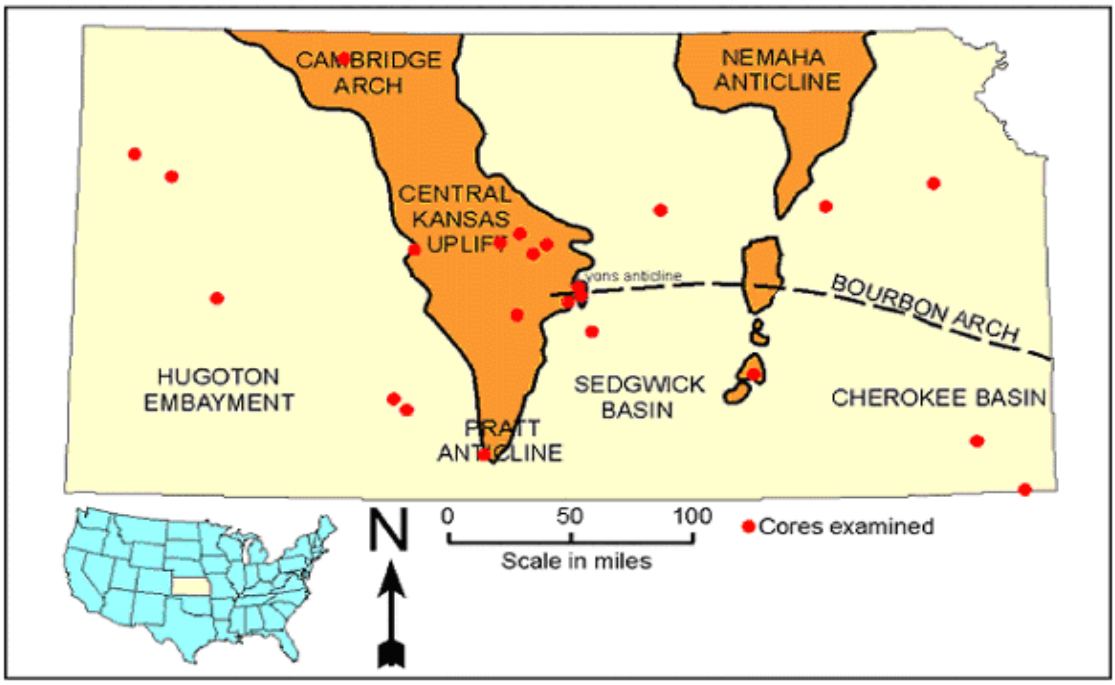
Source: Kansas Geologic Survey Postcard

Figure 5 is an east-west geologic cross-section.



Source: KGS "Geologic History of Kansas"

Figure 6 depicts the major structural features in Kansas from KGS Open File Report 2003-59.



A

Figure 7 depicts the principal aquifers of Kansas.

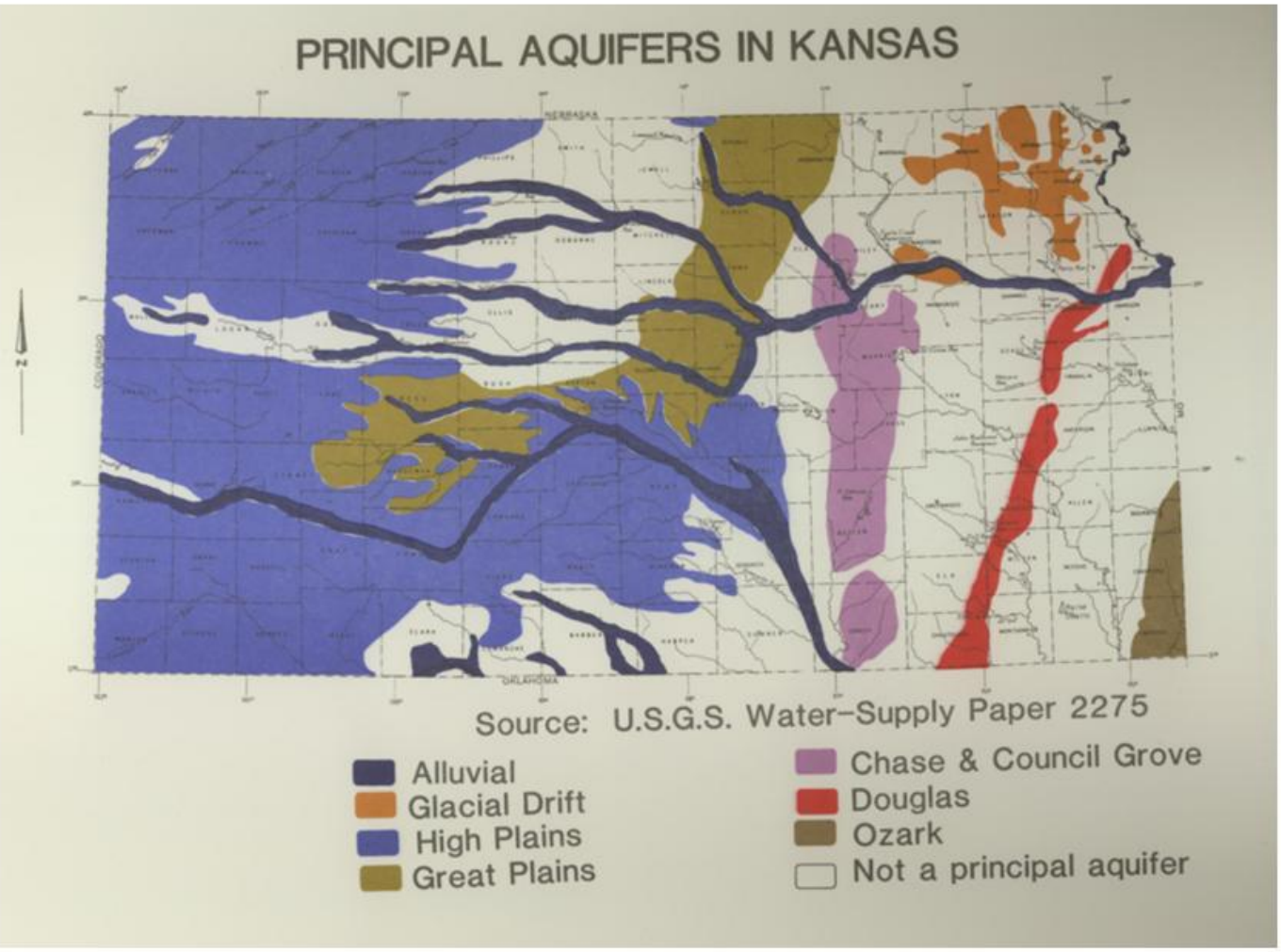


Figure 8 depicts the thickness and extent of the Hutchinson Salt member of the Wellington formation.

HUTCHINSON SALT MEMBER

WELLINGTON FORMATION

PERMIAN SYSTEM

Extent and Thickness

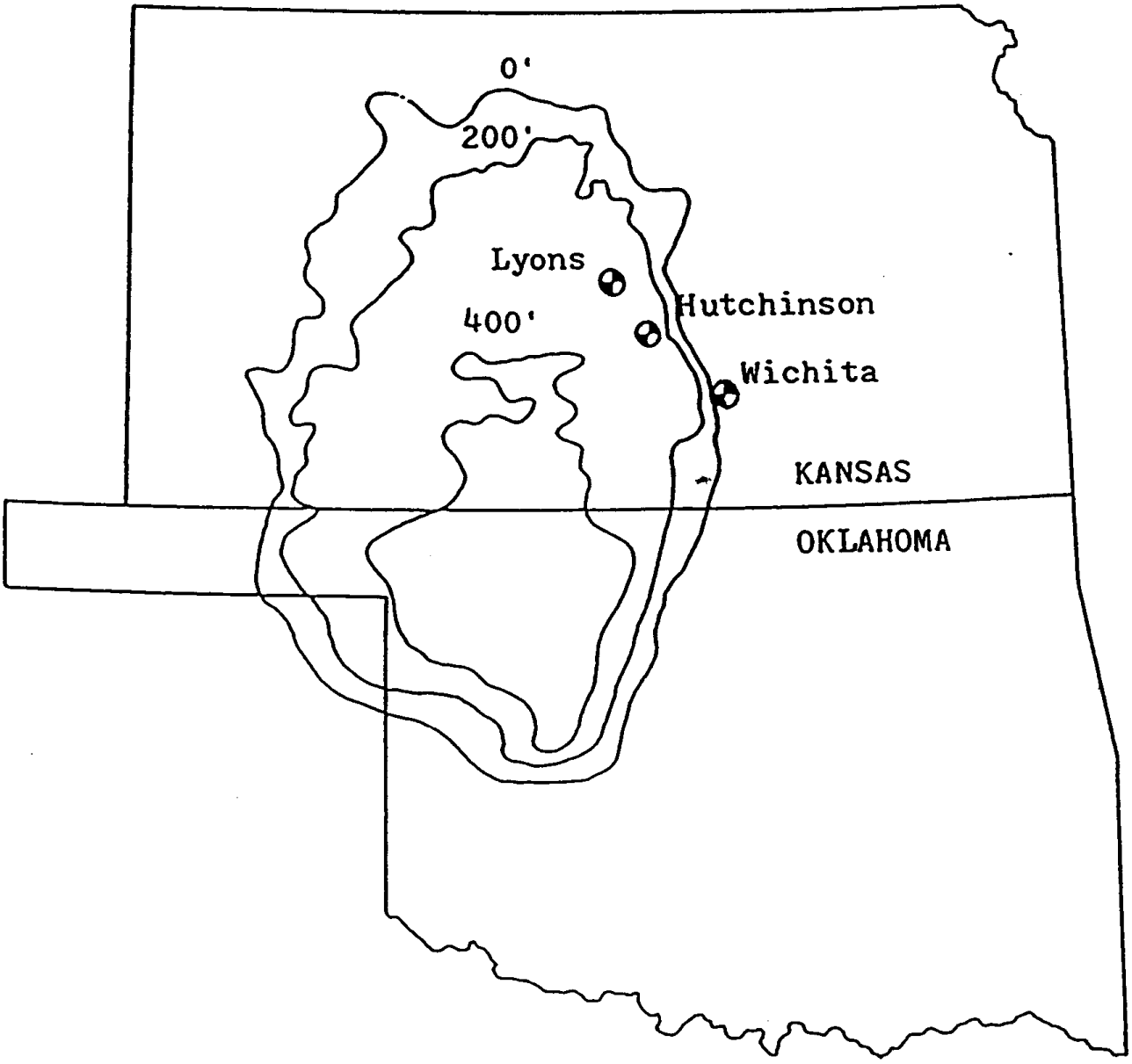


Figure 9 is an east-west cross-section showing the Hutchinson Salt member of the Wellington formation.

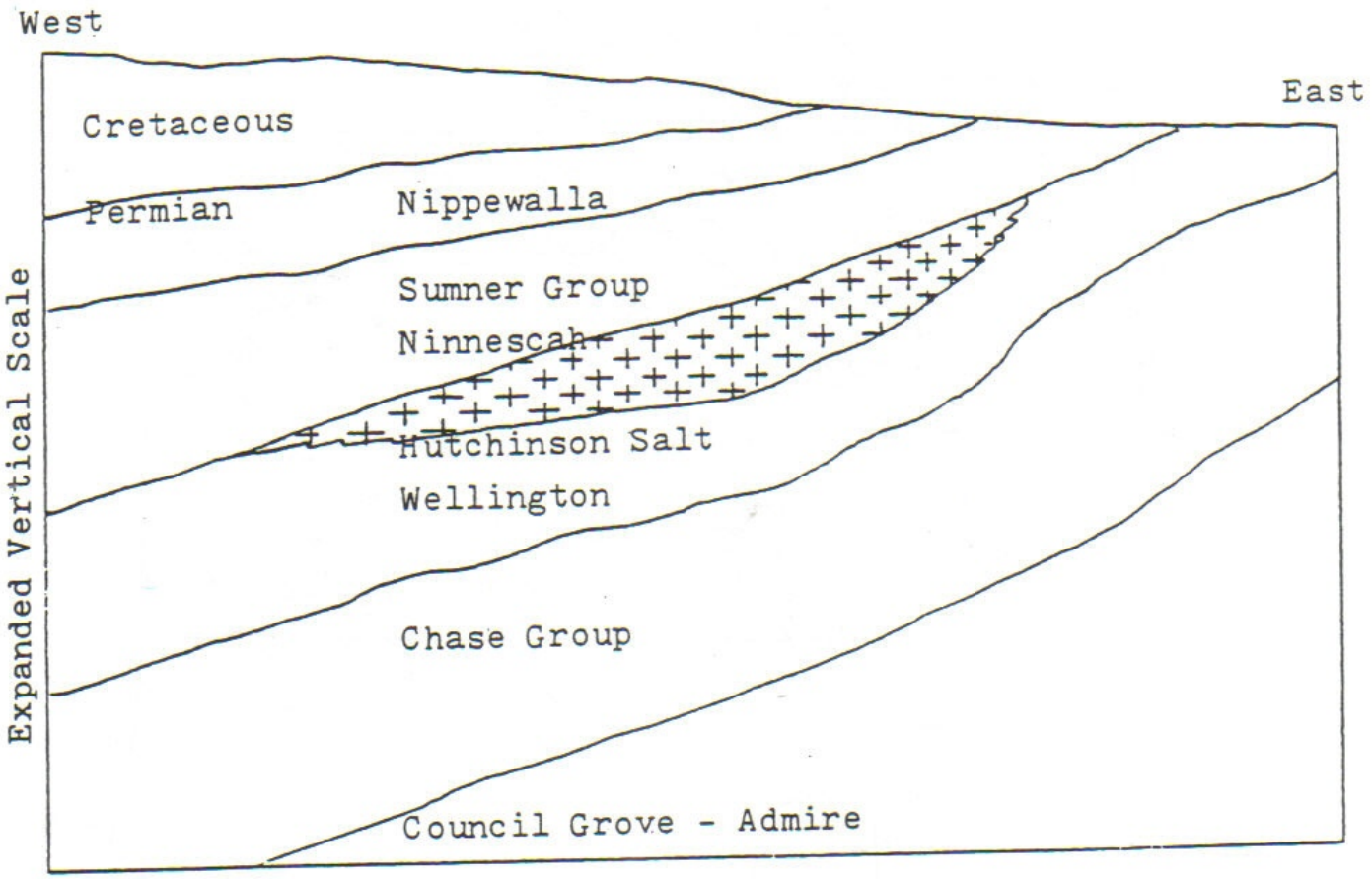


Figure 10 is a typical Class III well design.

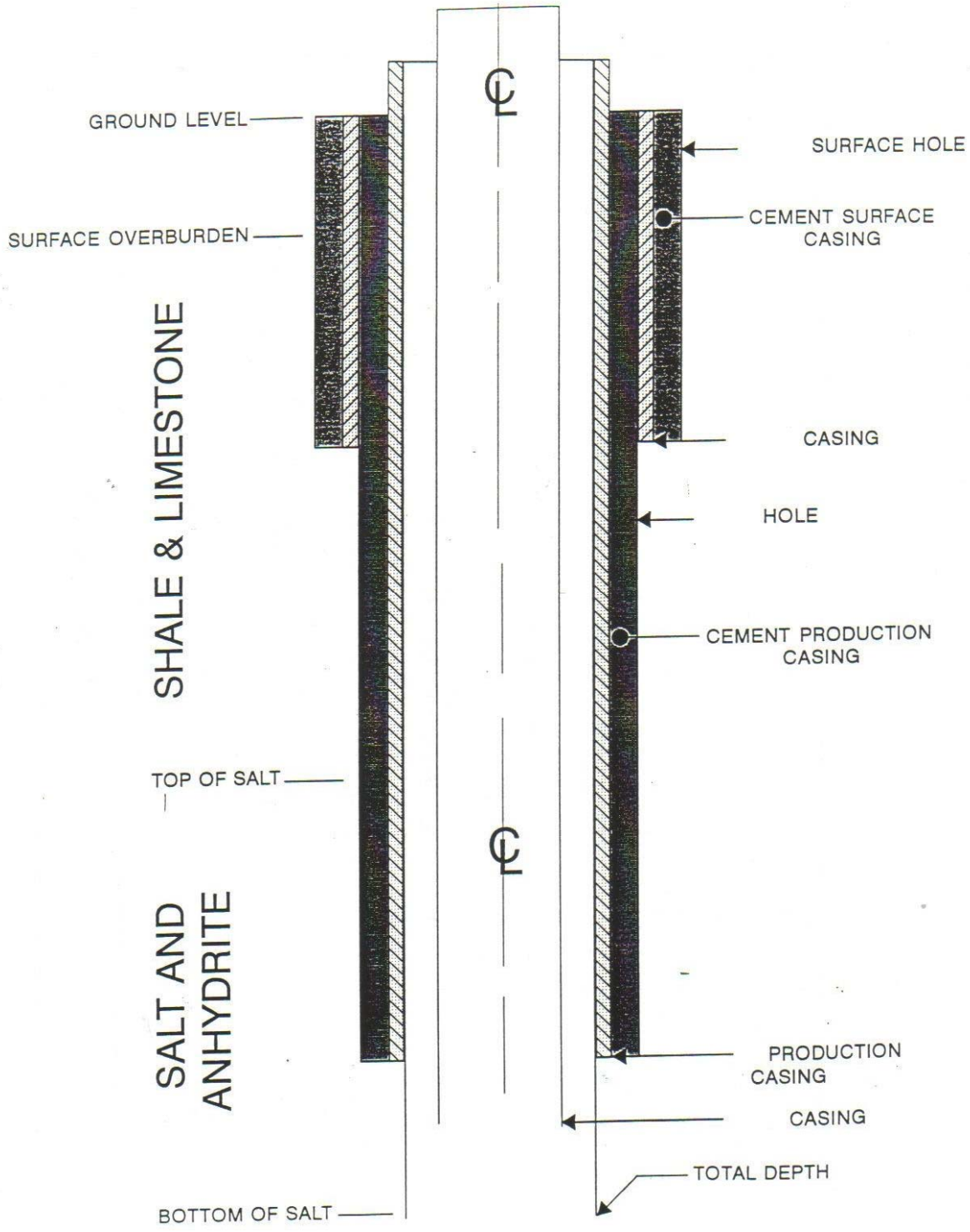


Figure 11 depicts typical 5-spot gallery.

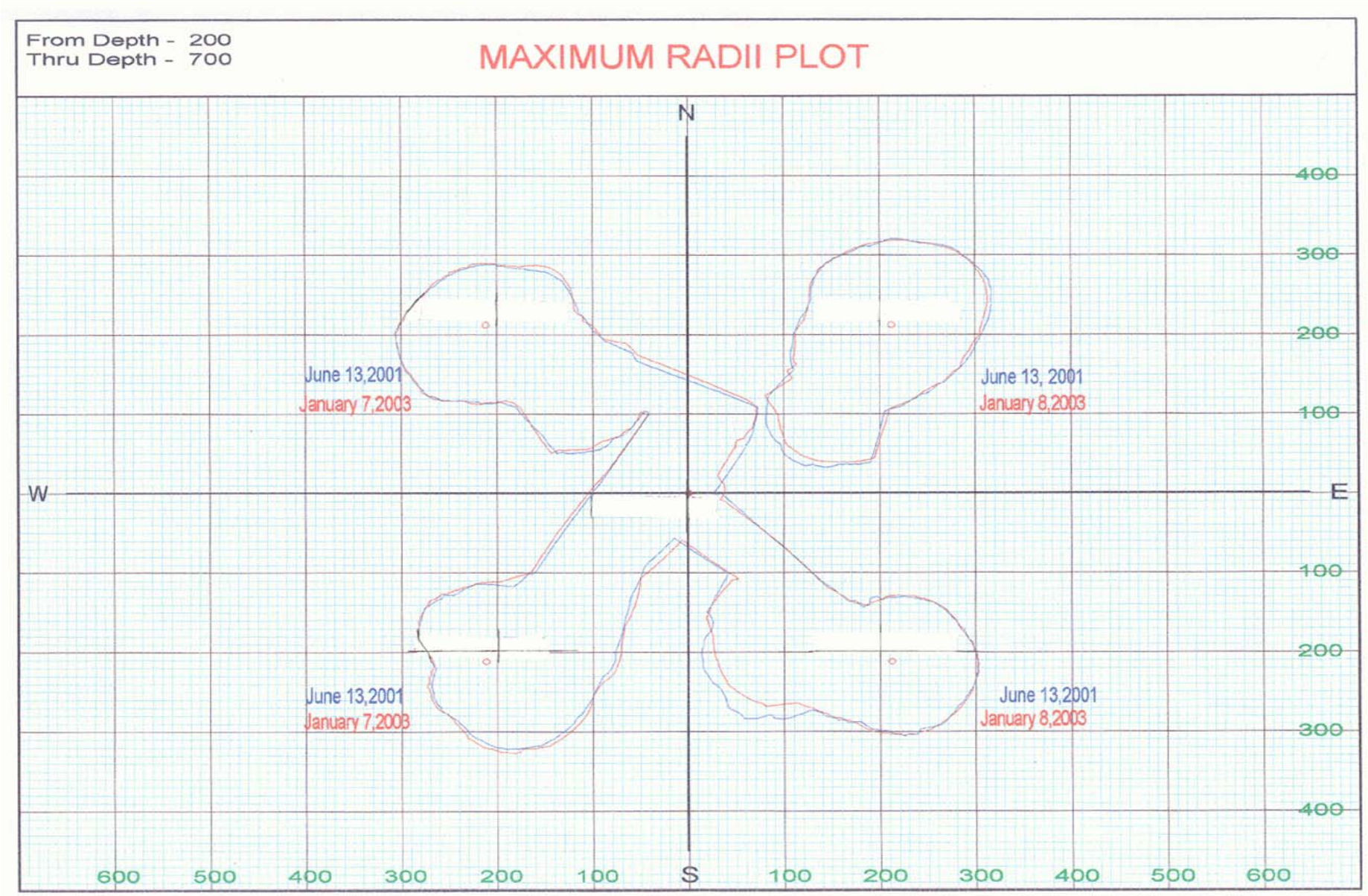


Figure 12 depicts a typical horizontal well gallery.

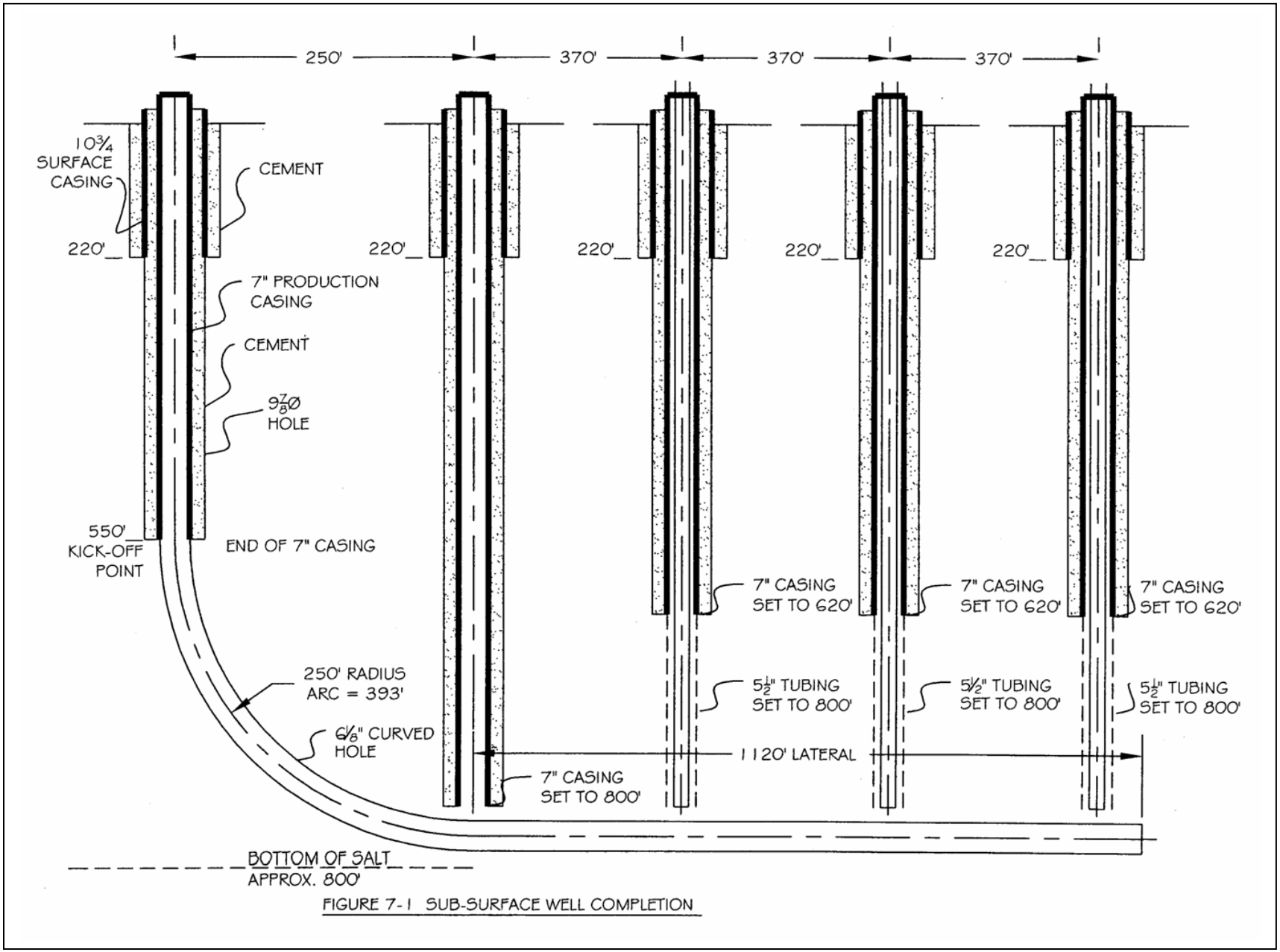
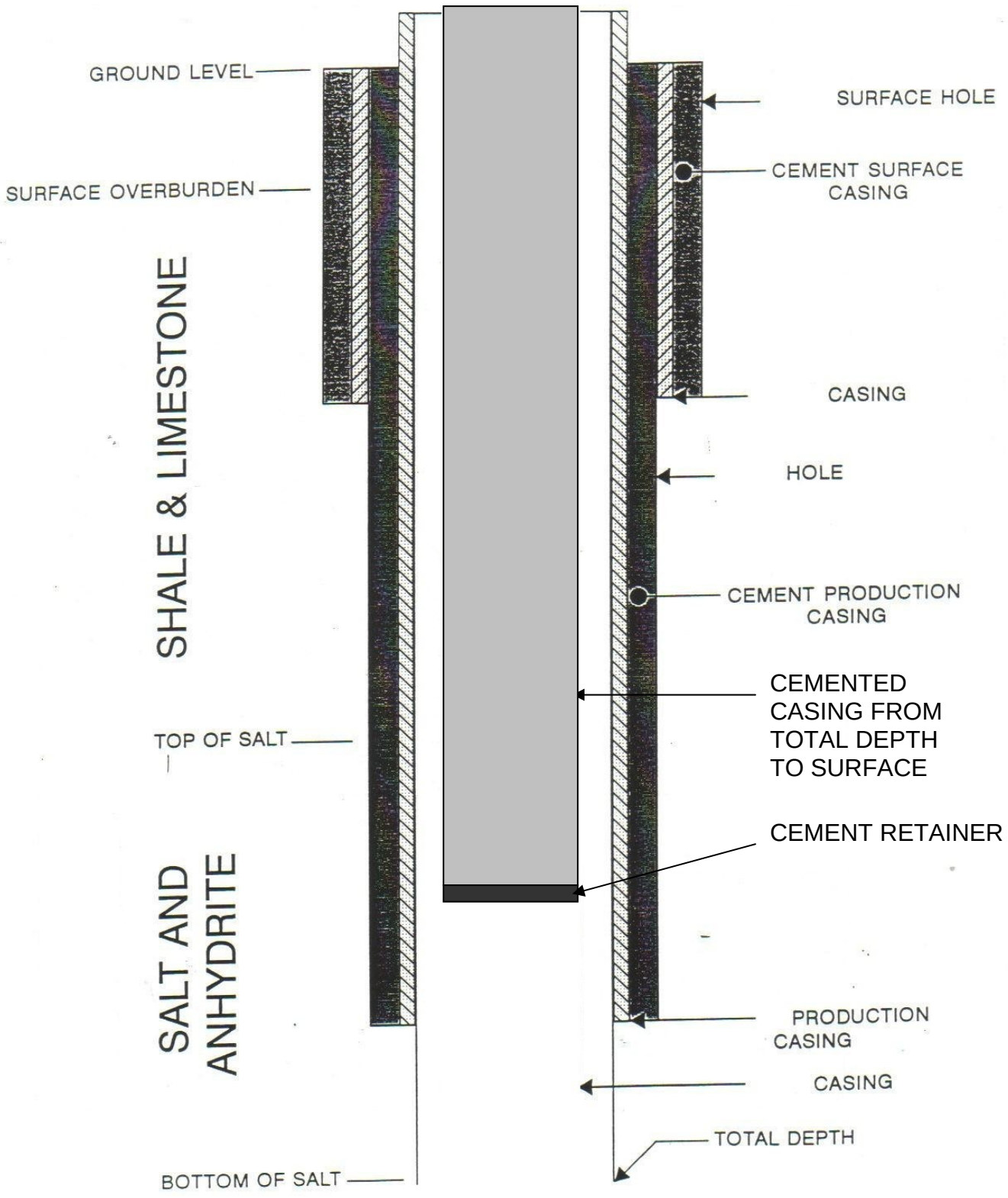



Figure 13 depicts a typical plugged Class III well.