# KANSAS GEOLOGICAL SURVEY
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NATURAL RESOURCES OF SOUTHWESTERN KANSAS

By

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by Lynn Watney
text and selected illustrations

# NATURAL RESOURCES OF SOUTHWESTERN KANSAS

Geologist/subsurface/rocks--Introduce to you and discuss the geology of those significant resources in southwestern Kansas, namely natural gas, crude oil and water--emphasis on gas and oil.

Mineral resource though includes those substances in the earth such as water, coal, oil and gas that have economic importance and occur in sufficient quantities and quality to be economically produced; in Kansas mineral resources also include rock salt (halite) from the Hutchinson and Kanopolis area, clay, sand and gravel, limestone (cement, building stone, road aggregate), other by-products such as helium, carbon black impt commodities.

Like to emphasize the geologic occurrence of natural gas and oil found in SW Kansas, but will also touch on the geology of an important water reservoir unit in W KS, the Ogallala Fm.

Introduce you to some basic geologic principles and an overview of the geologic framework of Kansas which SW KS is a <u>part</u>.

As an introduction then:

(1) Concepts, tools of trade of geology, principles

(2) Introduce you to rock column in Kansas, excursion across Kansas via slides visiting some of outcrops emphasizing those rock layers containing oil and gas in the subsurface of southwestern Kansas

(3) Examine subsurface geologic structures (uplifts and basins) that divide state into regions of accumulation of petroleum e.g., again with an emphasis on SW Kansas

SANDSTONE

1 CONCEPTS

Oil and gas occur most frequently in layers of sedimentary rocks; sedimentary rocks include three basic types:

a) Rocks composed of consolidated sand grains--(sandstones), particles laid down by water and wind--river bar, sand dune, beaches along shorelines where waves break and currents move and sort these grains.

SHALE

2 b) Hardened, compacted mud or clay--(shales) deposited in quiet environments beneath a column of water, generally in water such as in lake, lagoon along ocean coastline, or in the ocean itself away from the shoreline.

LIMESTONE

3 c) Skeletons and fine grained to microscopic, broken particles of marine organisms that secreted $CaCO_3$ (lime) hard parts--clam, oyster, shrimp,--(limestone) (lithified lime mud and skeletal debris).

SALT

4 d) Lakes or arms of the sea where evaporation concentrates salts in water result in precipitation of evaporate minerals such as rock salt and gypsum--hot, arid climates along margins of a sea.

Sedimentary rocks represent environments on earth's surface where primarily deposition was going on rather than erosion--river channel, valleys (deposits laid down by river comprise flood plain); at lower elevations near sea level--coastlines--deltas (Miss. Nile), beaches and associated islands also built along coastline (Galveston Island, Cape Hatteras). These are environments for the deposition of sandstones and shale.

Limestone--warm tropical areas, shallow marine, away from major rivers, Bahamas, SO Florida--beaches and shallow lagoons where $CaCO_3$ secreting organisms live.

Reefs--(Great Barrier Reef of Australia extend nearly 1000 miles on Australias east coast).

Sediments preserved in areas that subside and new sediment buries old. As the environments change so do the rocks. Sedimentary rocks tell us about the environments that once existed at a particular place; Sedimentary rock layers are like a page in a book, bottom is oldest, top is youngest.

Crude oil, natural gas, as well as coal, lignite and oil shale are
fossil fuels that occur in sedimentary rock layers; while coal occurs
as distinct beds sandwiched between other strata. Petroleum on the other
5 hand is trapped in pores of the rock - (open spaces) such as between grains
in sandstone (pores formed between sand particles after they were deposited).
In limestone pores also result from partial solution of the rock (blue-
6 pores; limestone quite soluble).

Usually pore space involves 10-20% of rock volume.

Sandstone and limestones form layers in subsurface; their pores either contain freshwater or brine or petroleum. Speak of petroleum-containing intervals as reservoirs (NOT open pools or rivers).

Fossil fuels actually represent stored energy from the sun from times long, long ago (solar energy).

Coal and petroleum--altered remains of plants and animals. Geochemical studies reveal that these complex organic remains were transformed by heat while buried with sediment layers deep within the earth (1000's of feet).

Coal now mined in eastern Kansas at the earth's surface represents plant remains deposited some 300 m.y. ago and buried to depths of at least several thousand feet. Coal represents once flourishing forests which contained large ancestors of ferns and conifers (Penn.). Heat and pressure with burial compacted the pile of decaying OM on the floor of the forest and transformed the organic molecules. Layers of coal one ft. thick probably represent an original accumulation of over 10 feet of decaying leaves, branches, and tree trunks.

## PETROLEUM, WHAT IS IT?

Term referring to both gaseous and liquid hydrocarbons, simply molecules formed by various combinations of the atoms carbon and hydrogen.

Methane--commonly referred to as natural gas, ethane, propane, butane, gasoline range HC on up ($C_5$ to $C_{10}$), or diesel fuel ($C_{14}$ to $C_{18}$/molecule), (more carbon atoms in $\int$ arrangements) sulfur, nitrogen, oxygen are also present (catalytic converters, polution abatement, S&N oxides).

Crude oil a complex mixture of gasoline range HC to very heavy molecules of carbon; crude oil characteristically range from consistency of molasses to that of water. Heavy oil is vicious and difficult to remove from reservoir. Oils in SW Kansas generally not as viscious as in E. Kansas.

Elevated temperatures during burial of sediment are required to form oil as well as coal. Petroleum is generated from organic matter usually dispersed as microscopic particles in shales (lithified muds and clays).

Oil Shale--insufficient heating

OVERHEAD

Summary Flowpath for Oil Generation from OM

Layers of shale containing adequate amounts of preserved OM (algae, plant remains etc.) (~2% by wt.) kinds of shale are potential petroleum source rocks--where oil originates. Sediment must be buried to depths of several thousand feet, with temperatures of 100°C or better, cooked over time in the millions of years for the oil to be produced (pressure cooker). Original OM is transformed to new chemicals that finally become HC-like.

Petroleum expelled from shale and migrates along porous carrier beds (ss-ls layer) or fault or fracture. Petroleum less dense than water. Petroleum (not mix with) displaces water in pores and migrates upward.

Geochemical techniques allow us to measure in quantitative fashion amount heating + match crude oils with source rocks (fingerprint) cross section/view rocks from side.

7 L Anticline Diagram

Petroleum migrates to highest position in porous rock layer, (oil in blue Anticlinal trap with overlying seal).

Stratigraphic trap with vertical and lateral seals.

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Handouts geological map of Kansas--rock column in Kansas

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8,9 L Grand Canyon R Geologic Map with Cross Section

The emphasis on petroleum and coal bearing strata. Geol. map shows distribution of rock layers as they are found on surface of earth. Chase and Council Grove Groups part of L. Permian Series are shown in light blue on this map. Outcrop of reservoir rocks of the Hugoton and Panoma Gas areas. Actually this light blue layer comprised of some 33 ∫ formations and some 70 beds alternating ls, ss, and shale. Map is gross generalization.

On cross section below this map--a profile through the upper earth's crust illustrates that these individual layers of rocks are dipping westward in eastern Kansas. Oldest rocks at surface are in eastern Kansas (Mississippian). Progressively younger layers found to west as the layers dip into the subsurface. Get impression that a lot going on in subsurface that is not seen in surface layers -- absolutely true.

10 L Midcontinent Geologic Map HOLD

Left is geologic road map of midcontinent region published by the AAPG (good buy). Westward dip of rock layers in eastern Kansas result of uplift in Ozarks of Missouri and Arkansas. Geologically called the Ozark Dome. At core of this uplift is exposed Pre-E igneous rock (dark brown), most ancient rock exposed in region. To the west outcrop the layers of limestone and dolomite of the Arbuckle Group of Lower Paleozoic age. This layer is buried over 1,000 feet below the surface upon arriving at the eastern Kansas border.

The Arbuckle Group, maroon layer on cross section, is an important freshwater bearing unit in the southeast KS and SW MO. Freshwater has moved into the shallow, nearby subsurface from the outcrop on the east. In central Kansas though where the Arbuckle is buried to depths exceeding 3000 feet, it is an important oil producing unit (reservoir) on an uplift called the Central Kansas Uplift. The pore system in this rock layer now contains oil and brine.

Now I would like to identify some other rock layers that contain oil, gas, and coal in Kansas as they are seen on the surface in familiar settings to you. Then later I will plunge back into the subsurface to discuss the structures and highlight southwestern Kansas.

Although I don't have a photograph to show you, the oldest layer of economic significance in SW Kansas is the Mississippian age limestone. Mississippian-age limestone outcrops at the surface only in extreme SE Kansas. Mississippian-age limestones produce oil and gas in SW Kansas at depths in excess of 5000 feet below the surface. Limestones contain abundant fossils all which suggests an extensive shallow sea once covered almost the entire continent during that portion of geologic time.

11 Aerial Photo

12 Strip Pit Highwall

Above the Mississippian Limestone in eastern Kansas is the Cherokee Group--comprised of alternating layers of sandstone, shale, and thin limestones. Although poorly exposed because these sedimentary rocks weather readily, strip mines expose the layers as shown here as they retrive the thin coal layers also found in this interval. The sandstones in this unit are lenticular (pinch out in cross section), are sinuous (snake-like) in map view, and are referred to as "shoestring" sandstones. Sandstones like the Bartlesville, Squirrel, and Redfork are prolific oil producers in SE Kansas. The same Cherokee interval also produces oil and gas in limited areas of SW Kansas included areas beneath the Hugoton Field.

The Cherokee sediments were deposited during the Pennsylvanian period some 300 m.y. ago. This period of time was also referred to as the age of coal, the Carboniferous.

Tropical Forest

The sea during Penn. was fluctuating back and forth over a broad, relatively flat region of the mid-continent. Rivers deposited their sediments on wide flood plains and built deltas seaward as the seas receded. Dense, flourishing swamps and forests covered the land. Plants on these level plains grew well under a humid, tropical climate. The sea periodically returned covering the dying vegetation with silt and mud.

The layers of shale, sandstone, ls. and coal accumulated to over 1000 feet in thickness in eastern Kansas representing the culmination of many periods of sea level fluctuations producing cyclic sediments or cyclothems (land had to subside). Raymond C. Moore, one of our previous state geologists became internationally known for his description and interpretation of cyclothems. Geologists today, world-wide are familiar with these deposits. Their understanding has shed light on similar deposits throughout the world.

These cyclic sediments continue into the subsurface of western Kansas.

13 L Geologic Map of Kansas

Another Pennsylvanian age unit that lies above the Cherokee Group is the Lansing and Kansas City Groups named after exposures described near the two cities. These rocks are alternating, thicker limestone and thinner shale beds with minor sandstones. Layers contain oil and gas in fields such as the Evaly-Condit field near Liberal.

14 HOLD R CUESTA TOPOG.

These limestones are more resistant to erosion than strata in the Cherokee and form the Osage hills of eastern Kansas where they outcrop (immediately west of the Cherokee outcrop).

15 HOLD R Quarry ls. (Portland)

The limestone layers are prolific oil and gas reservoirs in western Kansas where they are buried in excess of 3000 feet. In the outcrop they make good road aggregate, and an ingredient for portland cement as is the case of the Iola limestone shown here at Iola.

16 HOLD R <u>Penn. Fossil Scene</u>

Calcium carbonate skeletons of animals once living on sea floor during Penn. make up these layers of limestone. (Clear, warm tropical marine waters).

17 HOLD R <u>Porous ($O_3$ core)</u>

When ls is partly dissolved, large channel-like pores can form and become potential sites for oil accumulation. This core is a solution altered limestone from the Lansing Group in northwestern Kansas taken from a depth of 4200 feet below surface (actually correlate with outcrop 400 miles to the east). Similar limestone layers are present in SW Kansas and are locally productive of oil and gas.

18 HOLD R <u>FLINT HILLS</u>

This scene from the Flint Hills, this part of Kansas, is underlain by sequence of younger strata referred to as the Permian. The limestones are part of the Chase and Council Grove Groups.

19 HOLD R <u>Roadcut</u>

The name Flint comes from the abundant silica deposits so often present in these limestones at the surface.

20 HOLD R <u>Interbedded, varigated sh-buff</u> $CO_3$

This photo taken of a portion of the Chase Group in Riley County near Tuttle Creek reveals interbedded limestones and shale, each rock layer repeated many times--cyclothems. Each carbonate layer is potential petroleum reservoir in subsurface, but only in those layers where pores are developed. (FAULT)

The limestone layers in the Chase Group, have given up over 16 trillion cu. ft. natural gas some 2500-3000 ft. beneath the huge Hugoton Gas Area in southwest Kansas some 250 miles west of the outcrop.

21 HOLE R Cattle at pasture in Bluestem in Flint Hills

Cattle do not realize just how important the rocks they are standing on really are.

22 HOLD R Castle Rock in Eastern Gove County

Now move a considerable distance up the stratigraphic column to the U. Cret. These relatively young strata outcrop in western Kansas. The Niobrara Chalk deposited some 70 m.y. ago is another important petroleum reservoir here shown exposed at the surface. This chalk was deposited during a time when the sea level was probably as high as it ever was over Kansas. (Same age and kind of deposit as the main oil zone in the North Sea, the Danian Chalk.)

23 HOLE R Scholle SEM

This slide on the right is a highly magnified view of the chalk deposit obtained by using a scanning electron microscope, we see tiny, microscopic algae called coccoliths and single celled animals called foraminifera. They comprise the entire deposit of chalk up to several hundred feet thick. The pore space between the fossils is occupied by natural gas in northwest Kansas at a depth of 1000 to 1500 feet below the surface.

Ogallala is a layer of sandstone and shale deposited--around 3 million years ago, veneer over W. Kansas, important source of water.

24 L BASIN-UPLIFT CONFIGURATION

Subsurface of Kansas is divided into basin and uplifts. Uplift shown here as hatured area is a area where the Pre-E basement (igneous and metamorphic rocks) moved upward by internal forces active in the earth. The sedimentary rock layers are thinner over these uplifts than in the depressions alongside. These uplifts shaded here are not readily ID on the geologic map. Major movements occurred on the uplifts before the outcropping rocks were deposited.

25 HOLD R Nemaha Cross Section

Cross section extends from SW to NE in NE KS-SW NEB-SW Iowa. Colors denote dominant rock types (ls, sh). Notice the strong uplift in center of cross section. Some rocks are truncated (eroded and beveled) during the active growth of the uplift while later deposited rocks extend across top of the uplift. Wavy lines denote surfaces once exposed to erosion. These were land surfaces at one time. Rock layers immediately below these surfaces are weathered and many contain abundant cavities for potential oil and gas accumulation. Petroleum tends to migrate to places where rock layers are arched or domed--anticline. This major uplift is the Nemaha Uplift and is locally productive of oil and gas, e.g., E. Dorado and Augusta fields.

Only 600 ft. of sediment separate the Pre-E granite from the surface while over 4000 feet of sediment are present in the Forest City Basin to the east. The Nemaha Uplift is about 40 miles wide in NE Kansas, but narrows to only several miles before it exits the state in the SE. El Dorado field and Augusta are part of the narrow portion of the uplift as the Oklahoma City field is to the south.

Notice that the east side of the Nemaha Uplift is bounded by a steep fault (fracture with displacement). Several 1000 feet of displacement occur across this fault in the subsurface. Personnel at the Survey are recording microearthquakes in NE Kansas that are attributed to continued, but very minor movement on the fault (Humboldt fault).

26 L Map R CKU Uplift Cross Section

Another major uplift in the subsurface is the Central Kansas Uplift. It is much broader than the Nemaha, but has a very similar history. Rock layers of Mississippian age and older are uplifted and in part removed. Locally, rocks deposited in the Late Pennsylvanian (310 m.y.) rest directly on Pre-E at depths around 3500 feet. Arbuckle and Lansing Kansas City Groups are prolific producers over this uplift. Since the first discovery on the CKU in 1923 in Barton County, at the Fairport field, some 2.1 billion barrels of oil have been produced. Even weathered Pre-E granite locally produces on this uplift. Literally 1000's of wells have been drilled here and, while new discoveries are found on it each year, it is classed as a very mature region.

27 HOLD R Data Points for Geothermal Gradient Map

Map on right show points for control for a geothermal map of the state compiled by Don Steeples and Sandy Stavnez at the KGS.

Each point represents a well that has a corresponding electric log on file from which the temperature data were obtained. I show it to illustrate the high density of drilling over the Central Kansas Uplift, in south-central Kansas around Wichita and El Dorado, and in southwestern Kansas in the Hugoton and Panoma Gas Areas. The lack of control in southeastern Kansas simply reflects the unavailability of electric logs on holes drilled in this area. This area is actually very densely drilled.

Sedimentary rocks do provide record of events ever changing through time. To evaluate resource potential must interpret how rocks were deposited and what has happened to them since deposition.

Our knowledge of the vast region of this subsurface, where the main body of the sedimentary rocks lie, is revealed through abundant information obtained in the search for oil and gas. Operators of oil and gas wells are required to submit copies of logs describing the rock layers encountered in the form of both a written description of the rocks as well as wireline logs, better referred to as geophysical logs.

Also samples of the rock layers encountered are collected if the Survey has indicated an interest or if the operator just wants a record kept on the well.

In total the Survey maintains a collection of over 200,000 geophysical logs and sample logs. Rock cuttings from over 140,000 wells in Kansas are also on file. The information is costly to maintain, but it is essential information.

28 L Oil and Gas Map of Kansas HOLD

We finally come to the oil and gas map of the State of Kansas. Gas fields are in red and oil fields are in green. Relatively mature producing areas as identified by high drilling density as shown earlier (a lot of drilling toward field development).

The Salina Basin in contrast in north central Kansas is wide open for exploration, but those wells drilled so far have had limited success, if any. NE Kansas also offers potential for further development (recent discovery). Drilling success has been mixed. Western Kansas offers a lot of drilling opportunities. It will require a close look at the strata from wireline logs and samples to interpret favorable conditions for reservoir development.

Oil 29 SW KS Cross Section

The Hugoton Gas Area has produced over 16 trillion cubic feet of gas since its discovery in 1922. The Lower Permian Age Chase Group is the gas bearing interval at depths of over 2500 feet below the surface. Cores of this rock look very similar to the limestones and shales in the outcrop in Central Kansas. The field is one of the largest gas areas in the U.S. and is part of the Panhandle gas area in Oklahoma and Texas.

The trapping mechanisms that has allowed gas to accumulate is related to the pinchout of this reservoir bearing rock types. There is no large anticline involved in the trapping of the gas but rather a substantial monocline with rather gentle dip to the east as seen in the cross section.

30 HOLD STRUCTURE MAP

This map also indicates that the elevation on the surface of the upper limestone layer of the Chase Group dips gradually to the east and southeast.

The western portion of this outlined area on the diagram is actually that of the Panoma Gas Area that area which is underlain by the gas reservoirs in the Council Grove Group.

31 Annual Production Hugoton

Has peaked in 1972 at over 650 billion cu. ft. cum. production (12/80) 16.9 trillion cu. ft.

32 Annual Production Panoma

Recent peak in 1979 over 135 billion cu. ft., from Council Grove Group. Cumulative 4.6 trillion cu. ft.

I believe that there will be significant extensions of the Chase and Council Grove reservoirs north of these fields.

33 X-Section

Oil reservoirs have been discovered in layers beneath the Hugoton and Panoma Gas producing zones, namely in the Lansing-Kansas City, Cherokee, Morrow, and Mississippian. The first three units are Pennsylvanian age. These traps in these layers are much more ellusive and restricted in size. The reason is except in a couple of instances, is that the quality of the reservoir is highly variable and that the structures (anticlines) are rather subtle or non-existent. It is difficult to identify locations to test with the drill. One definitely cannot drill in a random manner when the drilling itself costs in excess of $200,000 and probably another $200,000 to complete for production. The risk is high, but using subsurface geology and geophysics, particularly seismic profiling, areas can be interpreted to be more favorable to drill than others.

One important oil reservoir actively being explored for today in SW Kansas and NW Oklahoma is the Morrow, a division of the early Pennsylvanian. The reservoir rock is a sandstone developed as lenses in shale. The Morrow does not outcrop at the surface in E. Kansas, but is restricted to the subsurface of SW Kansas.

The Morrow, the oldest Pennsylvanian unit in Kansas, forms a rapidly thickening wedge of sediment to the south into a deep basin called the Anadarko Basin in Oklahoma.

34 <u>Paleogeography--Late Morrowan</u>

These sediments were deposited in a shallow marine and delta complex occupying and consequently restricted to NW OK, SW KS, E CO, much like the illustration shown here. A veinlike network of rivers gathered sediment and water that were deposited at the sea. If we zero in on the shoreline environment of this time it might have been something like the following illustration.

35 <u>Morrowan Depositional Environment</u>

Examination of cores (long cylinders of actual rock samples) and interpretation of wireline geophysical logs have allowed geologists to make this interpretation. The sandstones shown here in the purple color are the reservoir rock. They are very discontinuous and occupy positions as bars within the river channel and as marine sand bars that face and parallel the shoreline (notice the scale). Some sands trend more north-south, others east-west. The complicating factor is that it just was not one delta and shoreline combination that built outward here, but several systems over several million years. The locations of the sands in map view and in depth varies significantly. The geologist tries to sort out the details to locate where the sandstones are, (their depth, geometry, and orientation). Each point of control is expensive to obtain as you well know. Needless to say, holes that are many miles apart, besides those shown here just fractions of a mile apart, make for a lot of consternation on the part of the geologist in locating these oil and gas bearing zones. Notice the distribution of dry holes ( ). Among the producing wells ( ).

36 Gentzler Field, Stevens Company

This field produces gas and oil from the Morrow from several of the sandstone units that I mentioned previously. The field was quickly brought on production in 1971. Notice that in the relatively short time since the discovery of the field that the oil production has peaked and the gas production is tappering off at over 1 billion cu. ft. per year. The production will probably decline slowly over the next 15 to 20 years at best.

This field is typical of those that are apt to be found in the Morrow: not a lot of producing wells, restricted in area, but generally good cumulative recoveries of oil and gas considering the number of producing wells.

37 Victory Field

Another oil and gas field with reservoirs located in strata below the gas reservoirs in the Hugoton Field is the Victory field in Seward and Haskell Counties. Oil is produced primarily from zones in the L-KC and Mississippian, but oil is also produced from the Morrow, Marmaton, and Cherokee. The graph of annual production indicates production peaked before 1970, less than 10 years after discovery. Note that production of oil and gas increased slightly in the late 1970's. With the rise in the price of oil it became economical to do additional drilling in this field and to maintain existing wells to increase production. This field is rather exceptional for the area in that it is a large oil field located on a prominent anticline. There have not been many of these large fields found in the last few years. To maintain the production levels in Kansas we will have to rely on the discovery of smaller fields and encourage the older fields to produce more.

38 Oil and Gas Production SW Kansas

During 1980 SW Kansas produced over 6.6 million bbls oil, over 10% of the total production for the state (Morton, Finney, Seward Counties were the major producing counties in this region). Kearney, Geary, and Stevens Counties provided a large proportion of the 570 billion cu. ft. of natural gas that SW KS produced. This figure is well over half of the gas recovered in Kansas during 1980.

39 Crude Production for Kansas

Last year Kansas produced just over 64 million barrels of oil. Production has went up only slightly in the last few years as the result of resurgence in drilling. Furthermore, we will never regain production levels that peaked in the late 1950's. Our reserve base has been steadily declining since the late 50's and we will continue to see it decline or at best level off.

40 <u># Wells Drilled</u>

The number of wells drilled in Kansas was at a record high last year. Nearly 6500 wells were recorded or drilled in the state. While most of these wells were drilled near existing fields as production and extensions for a success rate of 55%, only one well in seven rank wildcats drilled were successful. Morrow wildcats certainly fell in this last category. The average depth drilled for a well in Kansas is now around 3500 feet while deep drilling in SW Kansas is in excess of 5000 feet. For these and other reasons, SW Kansas can not be easily compared with the rest of Kansas. Western Kansas still offers a lot of opportunities for new oil and gas discoveries.

Finally, I would like to very briefly address a very important natural resource: water, a topic that has previously been discussed by another speaker. I will keep the comments limited to the geology of the Ogallala Fm., the prominent location, of the freshwater in SW KS.

41 <u>Saturated Thickness of Ogallala Fm.</u>

The Ogallala Fm. is a regional aquifer underlying much of the Great Plains. It is a sandstone and shale sequence of strata that was shed from the erosion of the younger Rocky Mountains to the west some three million years ago. This map depicts the thickness of water saturated sandstone in the Ogallala.

42 Close-Up Sat. Ogallala

A closeup of this map shows that in western Kansas much of the thicker saturated Ogallala is found in Stevens and Seward counties. Seward County alone is estimated to have 24 million acre-ft. of water in storage in this unit.

43 Bedrock Map Below Ogallala

A map of the bedrock surface directly below the Ogallala indicates a slope to the E-SE. The streams which eventually deposited the Ogallala cut valleys down into this bedrock. The sandstones in the Ogallala are thickest in the deeper bedrock valleys particularly at the confluence of a number of eastward flowing streams.

44 Local Thickness of Saturated Ogallala

This map again shows the saturated thickness of the Ogallala. The dark blue colored area with thicker saturation is the bedrock valley. The light blue area is even thicker, probably representing the confluence of several channels.

Leading now into my conclusions, it is interesting to note and of monumental importance to geologists that the processes of sand deposition and sediment accumulation in general in rivers and along seashores has not changed over geologic time (unformitarianism). Whether it is the Ogallala or the Cherokee or the Morrow, the geometry and internal properties of the sandstones can be explained and hopefully predicted, provided some information is known.

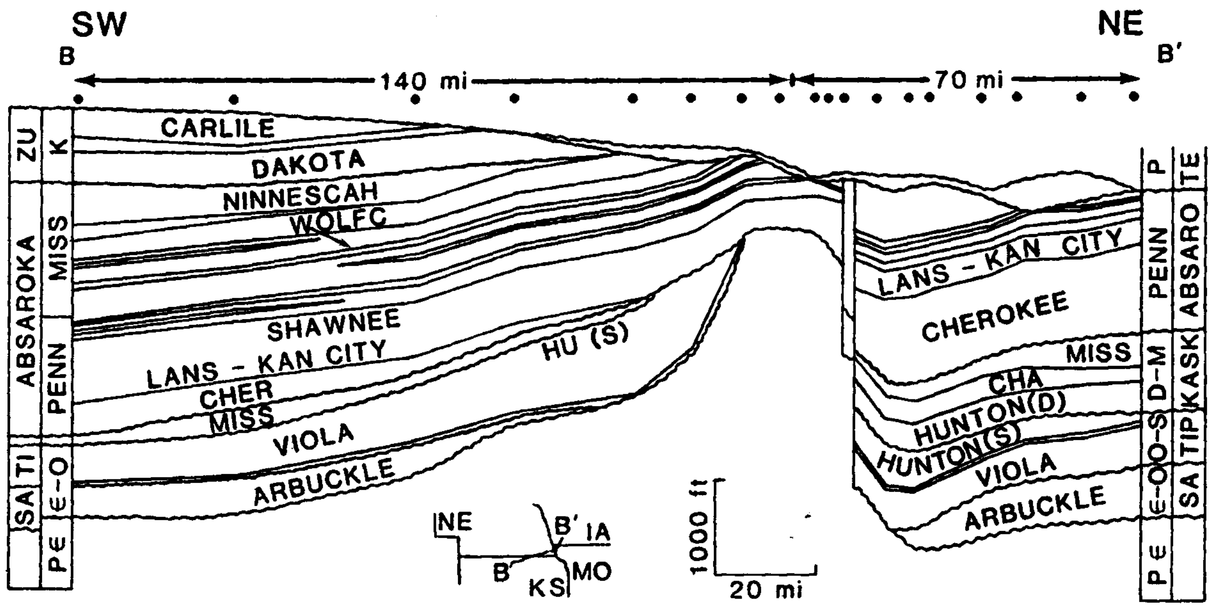
I have also suggested that the supply of fossil fuel resources in our state are declining. They are nonrenewable. Here today, gone tomorrow. How soon tomorrow will be, no one can really say. Oil and gas reserves peaked in the 1950's. Remaining fields to be found will be predominantly smaller than ones found in the past. It is possible that the reserves discovered in these new fields will meet the production needs, but the large reserve base that once was will never be regained. Tertiary oil recovery will become increasingly important in extracting oil from aging, depleting reservoirs. The technology to allow the injection of detergent-like chemical to wash out remaining oil is now in the small scale, pilot stage. Tertiary oil recovery may be a real boom to the Kansas petroleum industry when the technology is developed. SW Kansas will continue to be an extremely important part of our energy future, providing new oil and gas fields.

45 Large rivers did once wind down to a sea coast in SW Kansas millions of years ago. (LANDSAT)

46 It would have been possible long ago to see sand grains-picked up and sorted along a coast line forming beach deposits and barrier islands.

47 Application of latest technology such as seismic geophysical profiling of rock strata with computer enhancement will greatly assist companies in their future petroleum exploration.

Selected Illustrations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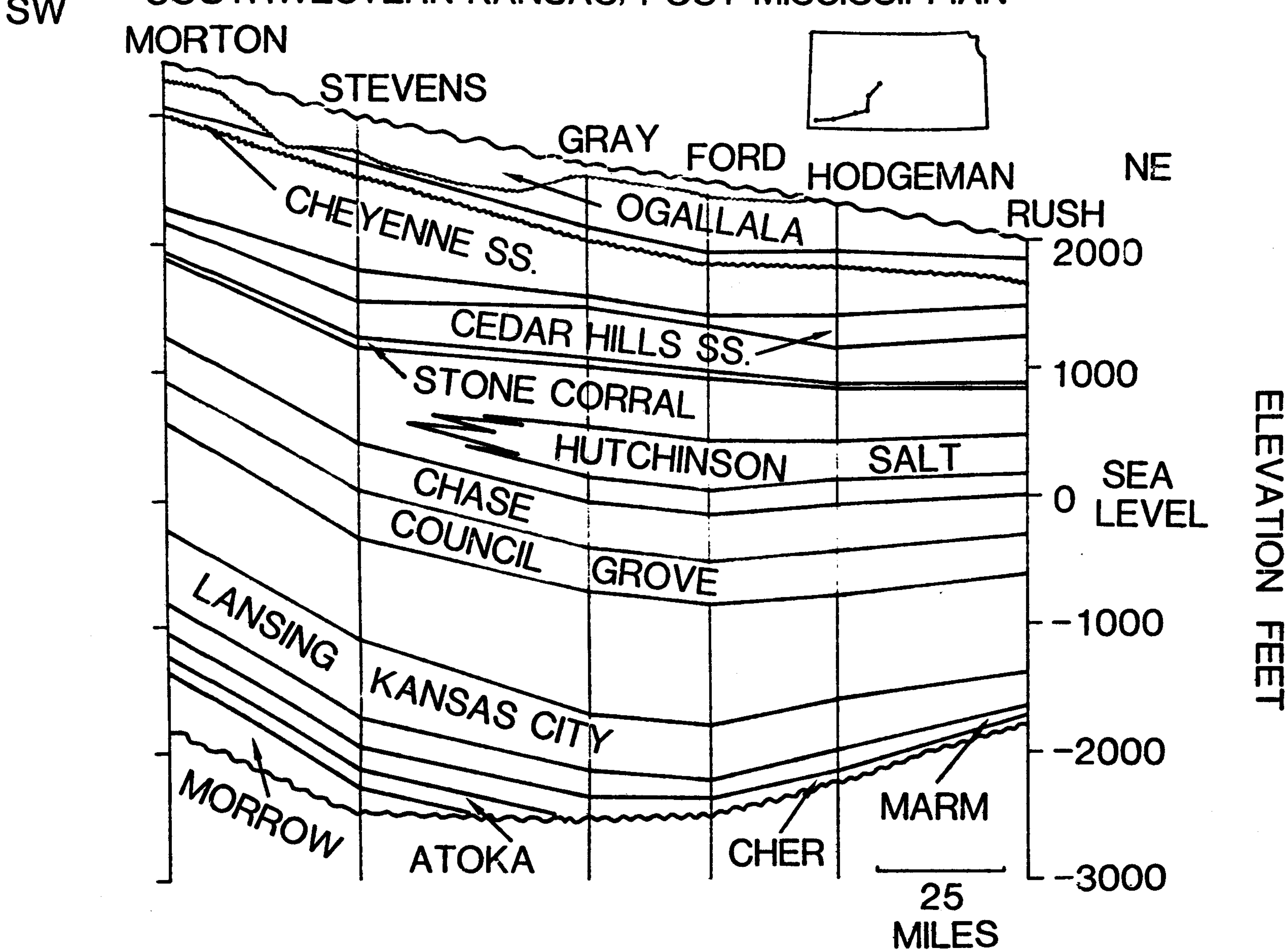
## SW TO NE STRUCTURAL CROSS SECTION SOUTHWESTERN KANSAS, POST MISSISSIPPIAN

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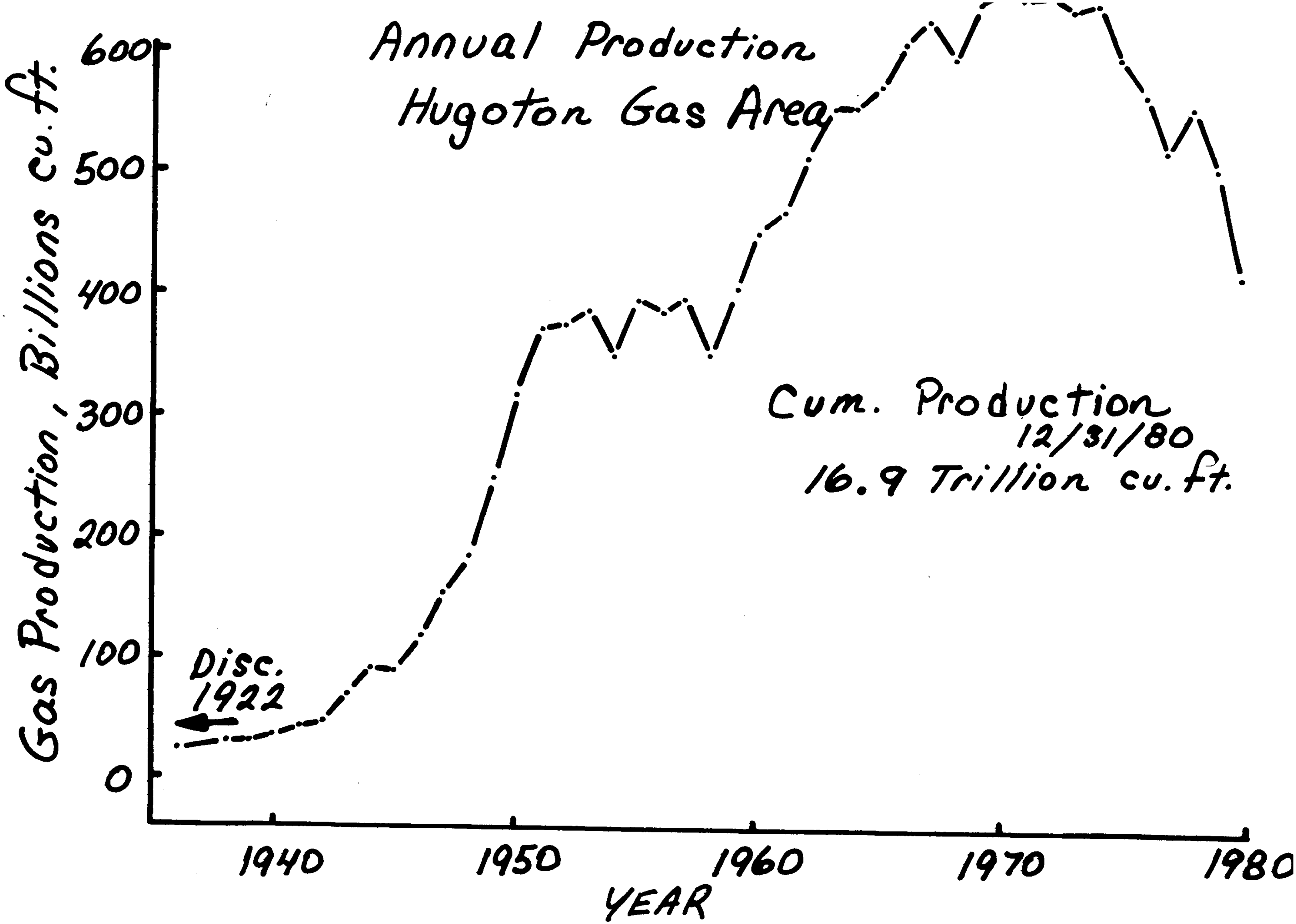
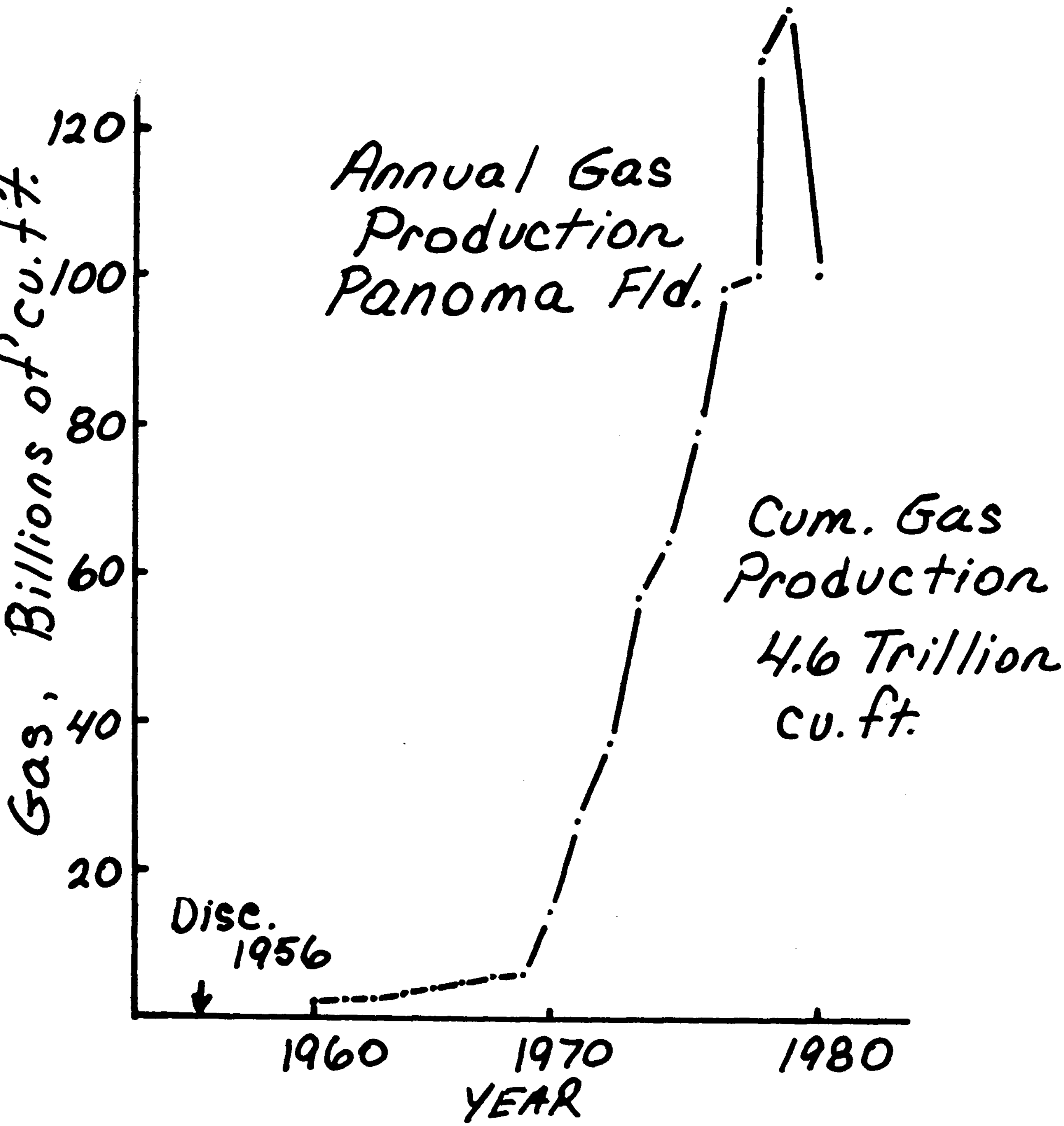
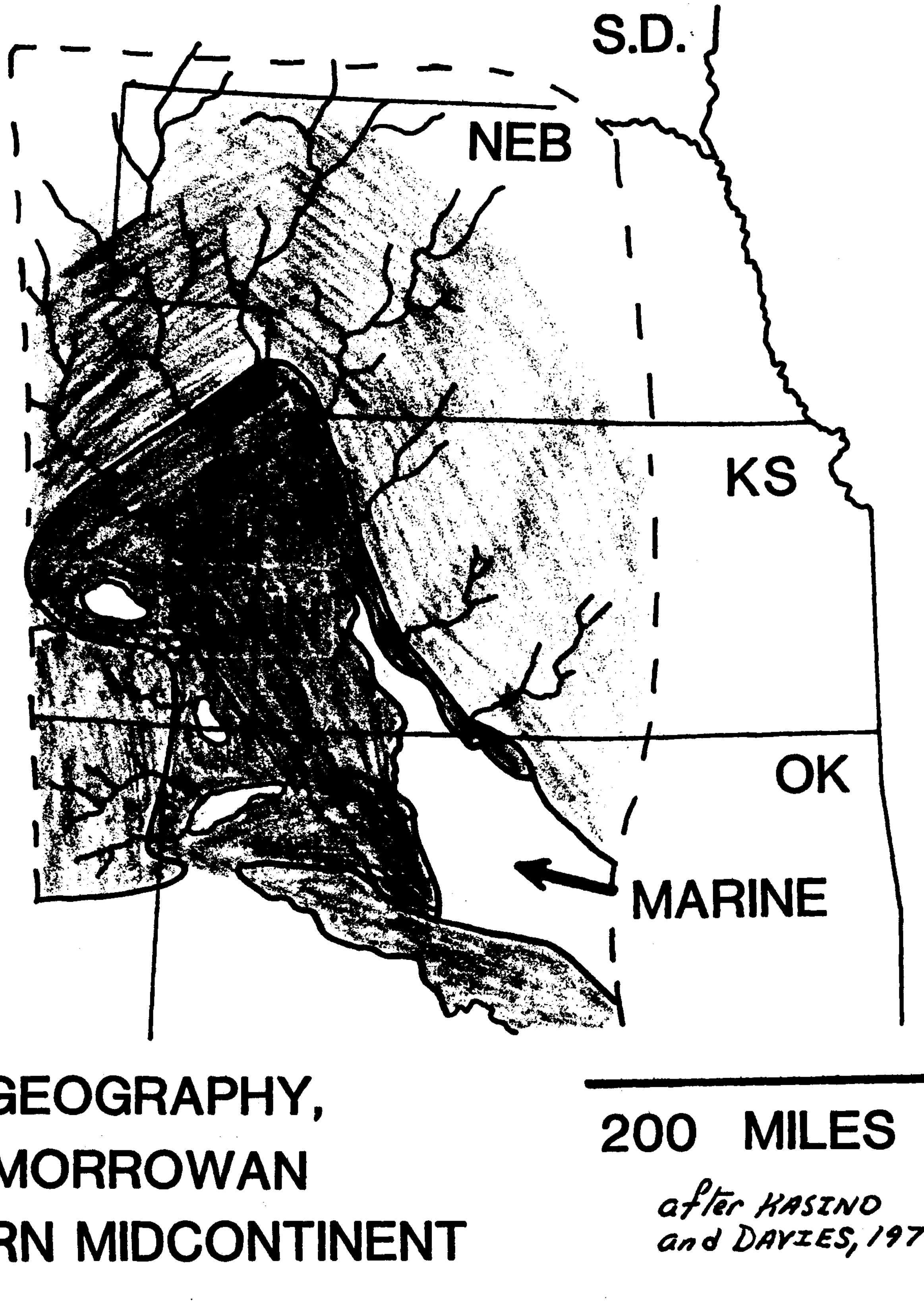


Annual Production
Hugoton Gas Area
Gas Production, Billions cu. ft.
600
500
400
300
200
100
0
Disc.
1922
Cum. Production
12/31/80
16.9 Trillion cu. ft.
1940
1950
1960
1970
1980
YEAR

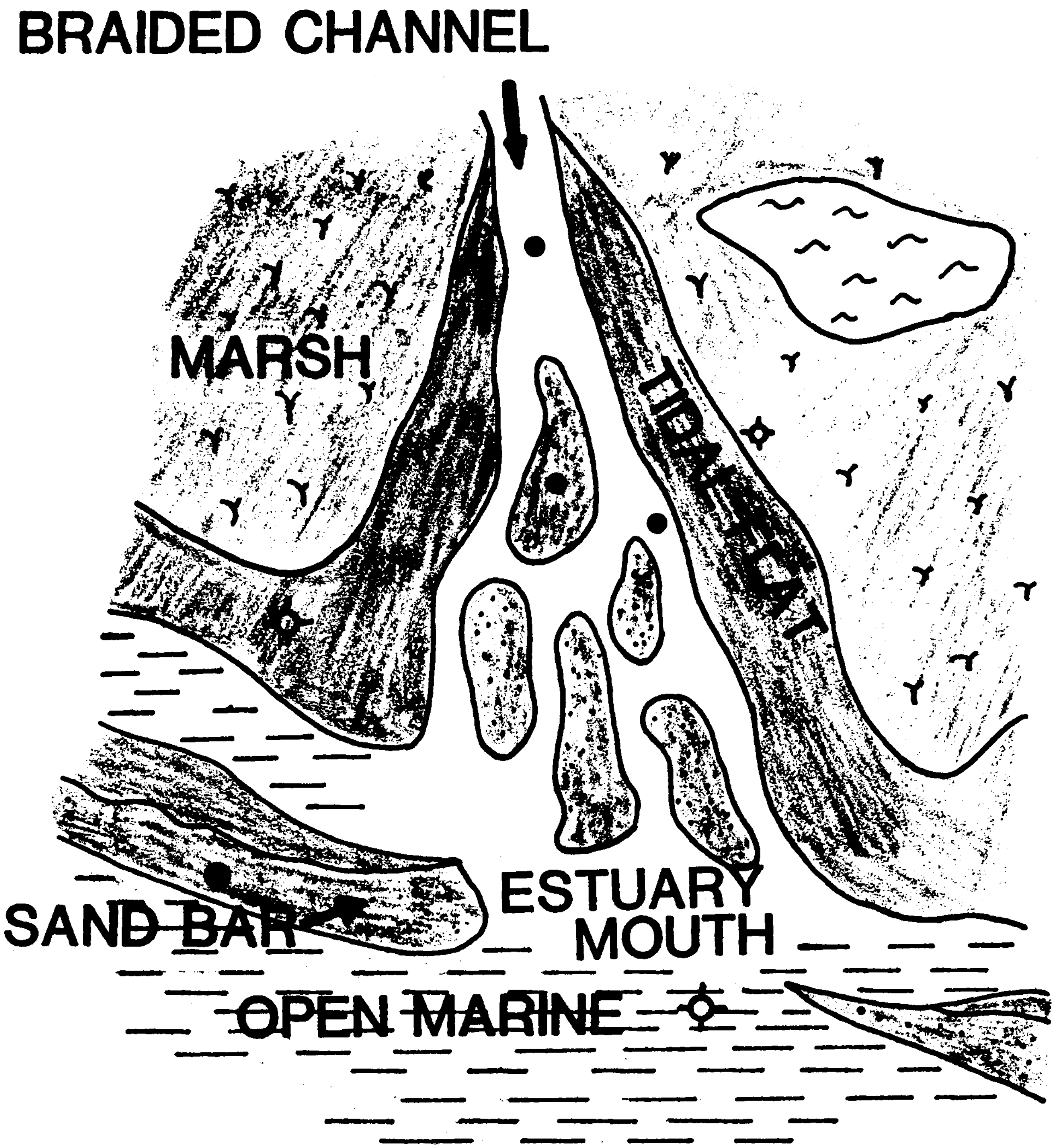


Annual Gas Production Panoma Fld.
Cum. Gas Production 4.6 Trillion cu. ft.
Gas, Billions of cu. ft.
120
100
80
60
40
20
Disc. 1956
1960
1970
1980
YEAR




PALEOGEOGRAPHY,
LATE MORROWAN
WESTERN MIDCONTINENT

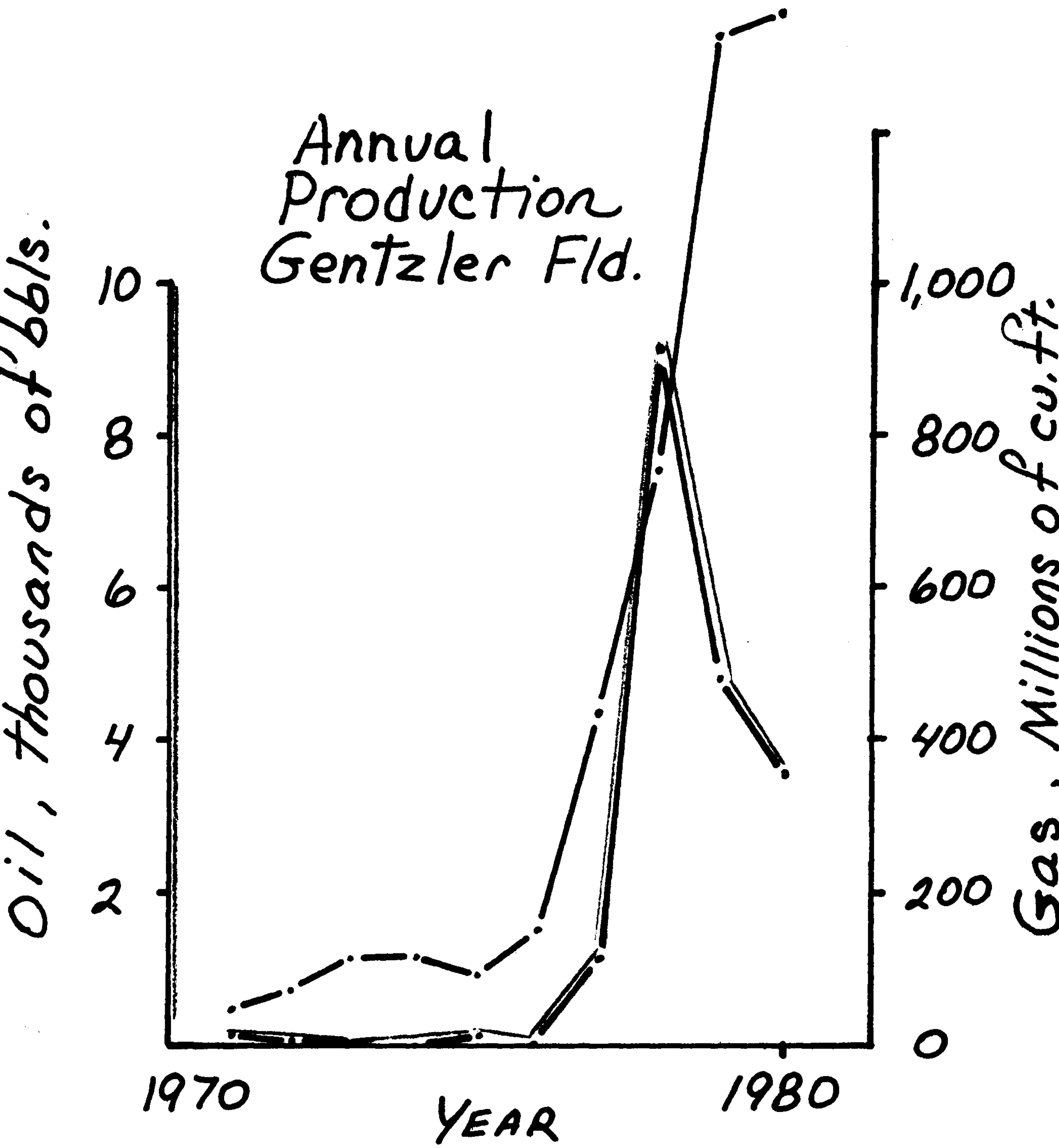
after KASINO
and DAVIES, 1979



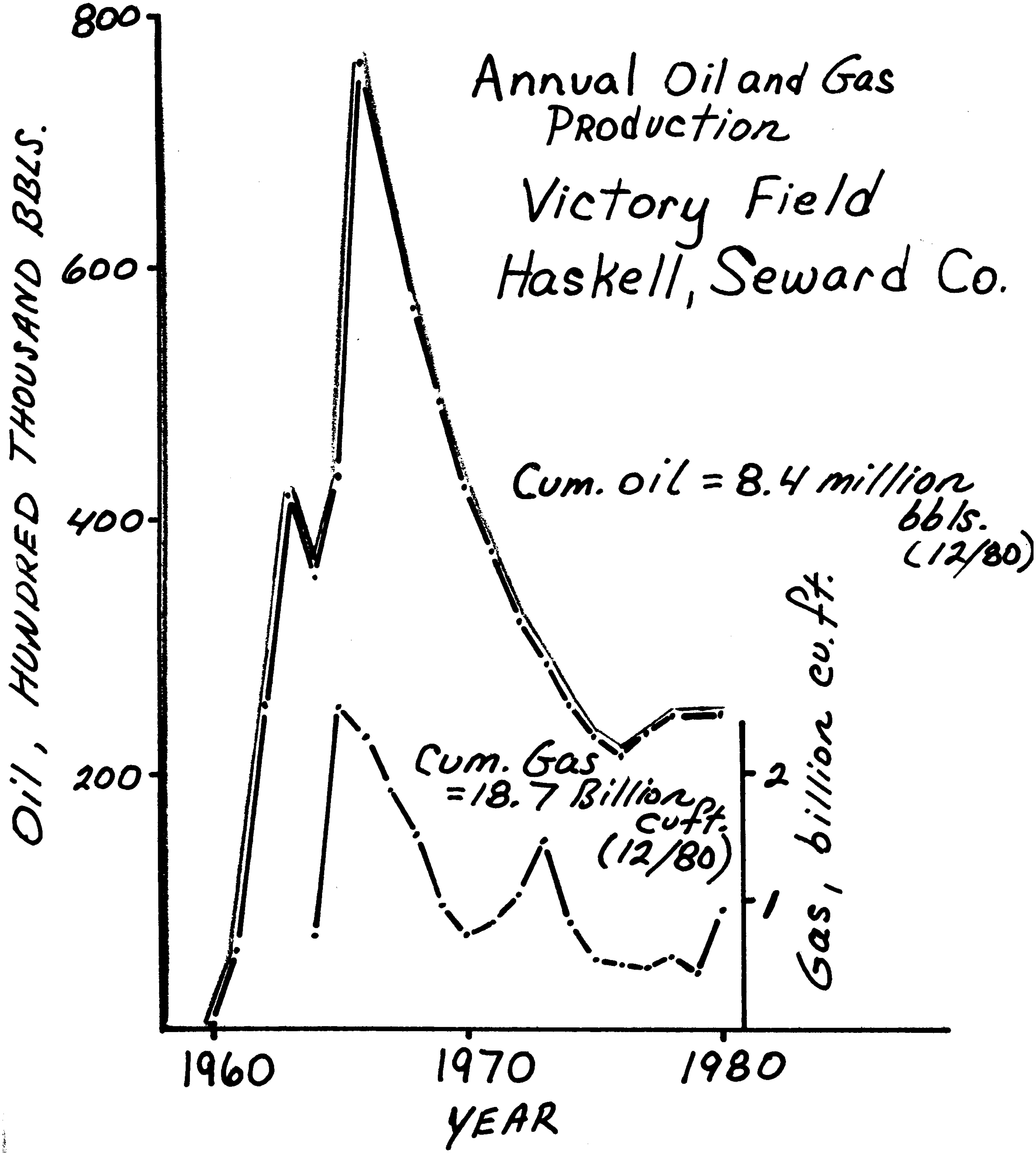

LATE MORROWAN
DEPOSITIONAL ENVIRONMENT

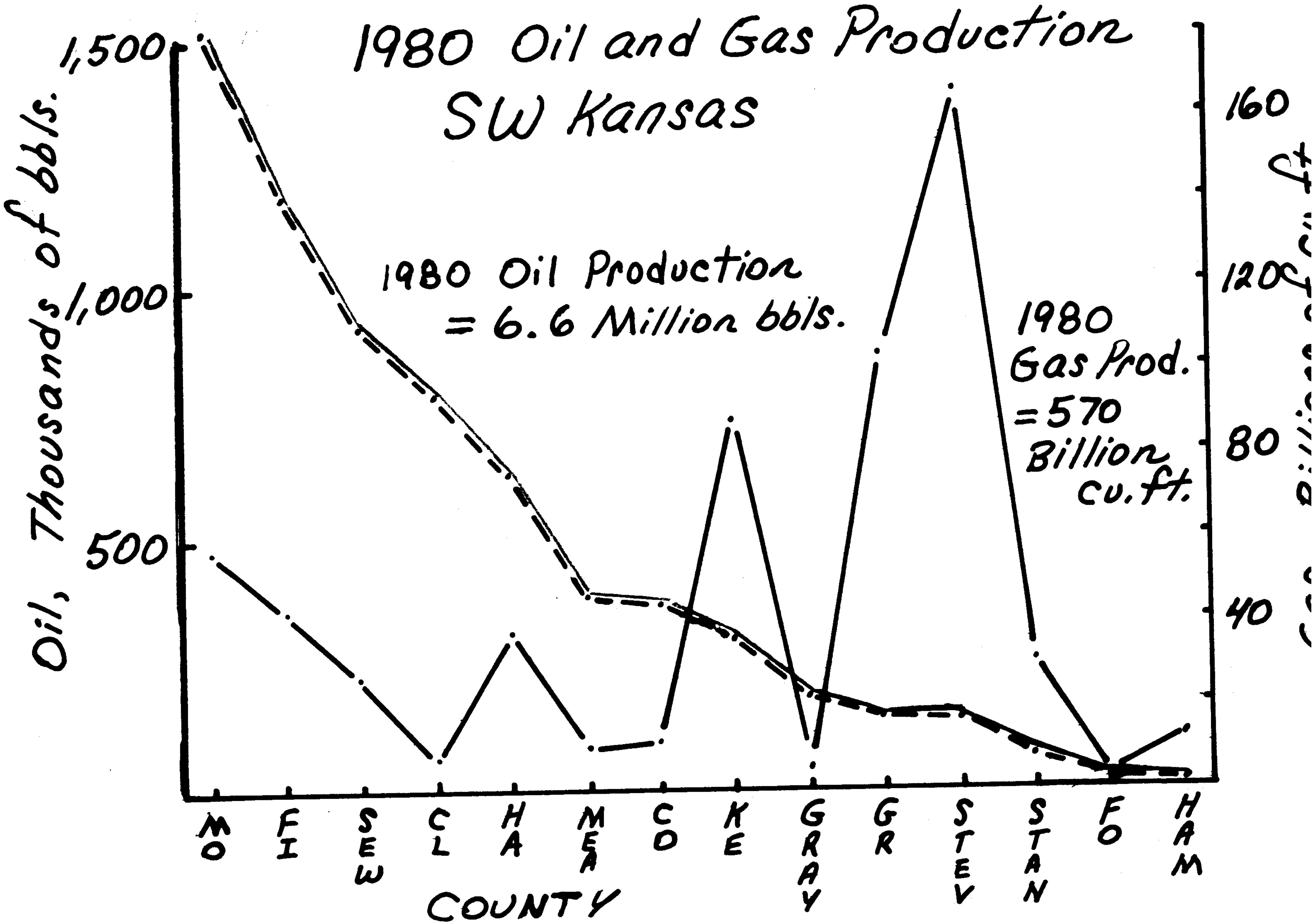
after KASINO & DAVIES, 1979

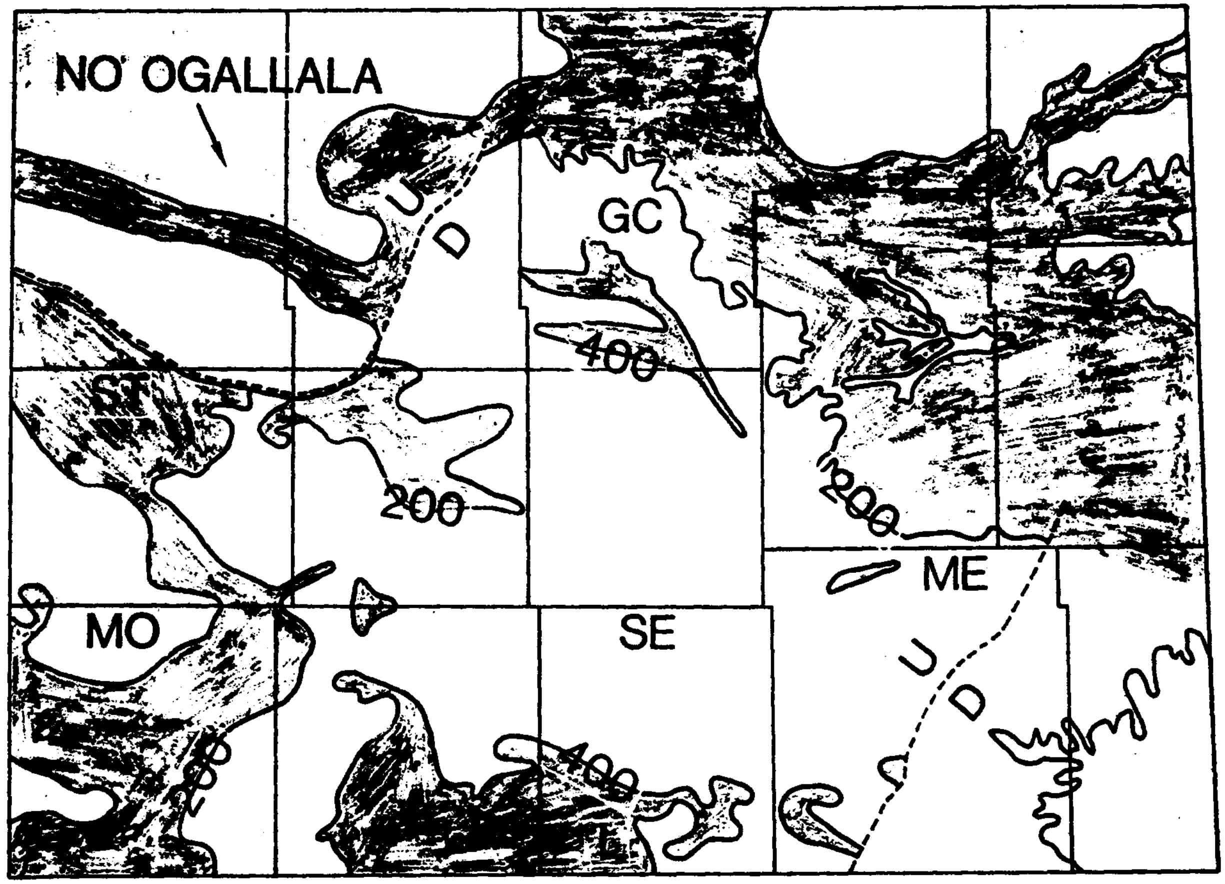
1 MILE



Annual
Production
Gentzler Fld.
Oil, thousands of bbls.
10
8
6
4
2
Gas, Millions of cu. ft.
1,000
800
600
400
200
0
1970
1980
YEAR


Annual Oil and Gas Production
Victory Field
Haskell, Seward Co.
Cum. oil = 8.4 million bbls. (12/80)
Cum. Gas = 18.7 Billion cu ft. (12/80)
Oil, HUNDRED THOUSAND BBLS.
800
600
400
200
Gas, billion cu. ft.
2
1
1960
1970
1980
YEAR


1980 Oil and Gas Production
SW Kansas
Oil, Thousands of bbls.
1,500
1,000
500
160
120
80
40
1980 Oil Production
= 6.6 Million bbls.
1980
Gas Prod.
= 570
Billion
cu. ft.
MO
FI
SEW
CL
HA
MEA
CO
KE
GRAY
GR
STEV
STAN
FO
HAM
COUNTY




THICKNESS OF SATURATED OGALLALA
CONTOUR INTERVAL: 200 FEET

20 MILES