

RELATIONSHIP OF EPEIROGENY AND SEDIMENTATION IN KANSAS

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Note: Illustrations included at the end of this open file report are numbered in the text.

A thin veneer of Phanerozoic sedimentary rocks were sporadically deposited over large areas of the Midcontinent during the Paleozoic. The sedimentologic processes that produced these thin, but widespread units were significantly affected by active epeirogenic deformation, the theme of this presentation. For a necessary perspective to the problem I will briefly summarize some recent thinking regarding tectonism on the craton and will then establish the tectonic framework of western Kansas, the area of focus of this presentation.

1. LEFT DISTRIB OF PALEOZOIC BASINS EASTERN U.S.

GEOL.(LIDIACK)

[shows the thickness of Paleozoic sediment in 1000's feet in blues, yellow, and rust color basins in letter code, Nemaha and CKU denoted

by basement faulting associated with them]

Kluth and Coney in a paper published in (1981) studied patterns of late Paleozoic deformation in the U.S. and concluded that plate convergence defined by the Appalachian- Ouachita-Marathon orogenic belt produced laterally directed forces which were responsible for the reactivation of older basement weaknesses. This orogeny began during the late Mississippian in the Appalachians and concluded by mid-Permian in the Marathons. Major late Paleozoic-aged structures recognized in the subsurface of Kansas; such as the Nemaha and the Central Kansas Uplift, were developed during the early Pennsylvanian coincident with the proximal plate collision bordering the southern Midcontinent.

The location of this intracratonic deformation was summarized by Kluth and Coney to be determined by: 1. Location of inherent weaknesses in the basement 2. Activation of only some of these weaknesses caused by a lateral stress field translated through the rigid basement. The actual location of deformation then is dependent on the trend and location of weaknesses and is a function of the major direction and sense of the stress. This hypothesis ties the tectonics of the interior to the orogenic activity along global plate boundaries.

However, there are also less spectacular but episodic movements of structural elements that represent some form of intraplate adjustment occurring without nearby orogenic stress. An example is the contemporary neotectonism recorded today by seismic activity and broad epeirogenic changes in elevation. We do know today that the continental interior is under compressional stress varying in

strength and direction from place to place across the continent. Furthermore, forces such as earth tides produce measureable diurnal deformation of the crust (Sbar and Sykes, 1973; Officer and Drake, 1982; Brown and Reilinger, 1980). These lesser forces dominated during the nonorogenic periods and thus may have been of considerable importance during active cratonic sedimentation.

2. LEFT PRECAMBRIAN GEOL MIDCON

3. RIGHT REGIONAL GEOL

ON the left screen is the geology of the Precambrian basement in the upper Midcontinent as illustrated in a map by Bickford and others. The various ages and types of rocks define the terrain of the Precambrian basement that resulted from either accretion on the edge of the craton or rifting of the interior of the young continent. The Precambrian terrains are fractured and faulted and have distinct boundaries all which are locations of weakness. Some of these weaknesses later became tectonically active and consequently define the locations of considerably younger structures. The trends of weaknesses generally follow these geophysical lineaments. The map on the right is the simplified basement geology and geophysical trend map for the northern midcontinent by Dutch. The map displays linear gravity and magnetic trends, paralleling elements of the Precambrian terrain. The prominent northeast trending 1.1 billion year old CNARS is shown here in purple. It cuts the older accretionary terrain that generally trends NW over much of Kansas. The CKU parallels the NW trending terrain and the Nemaha uplift the younger cross cutting CNARS.

5. UNANNOTATED POLE

6. UNANNOT 2ND VERT DERIV

Yarger has recently presented in a publication of the Kansas Geological Survey an interpretation of the aeromagnetic map of Kansas utilizing digital filtering of the original total magnetic field measurements. On the left and right screens are two such filtered maps, on the left one which he calls a pole correction map. As Yarger concludes the low frequency, generally NW trending elements shown here as lighter patterns of gray probably represent the deep-seated grain of the Precambrian.

On the right the 2nd vertical derivative map of the total magnetic field again published by Yarger illustrates light and dark lineaments and patterned regions where the gradient in the magnetic field is greatest. As Yarger states the map on the right identifies near vertical contacts between rocks of contrasting magnetization in the shallow basement such as might be produced by faulting or intrusion of mafic igneous rocks.

ANNOTATED POLE WS KS

ANNOTATED 2ND VERT

Sedgwick where located today.

The pole correction map on the left in western Kansas is now annotated with an outline of the CKU-CA and basement faults identified by Cole. Yarger identifies a prominent boundary between two contrasting-aged terrains shown by the green line. The CKU and many smaller structures parallel the dominant NW linear trends on this map in western Kansas.

The 2nd vertical derivative map on the right provides an enhancement of the short, subparallel, NE-trending, linear magnetic patterns of the CNARS. The linear segments likely represent a

graben and horst system intruded by gabbros while the area of attenuated magnetic signature outlined here in light green denotes thick clastic sedimentary strata of the Precambrian Rice Formation.

Notice that the southeastern portion of the CKU is underlain by abundant NE linears, its SE edge borders the west edge of the Rice Fm. and subparallels the NE linears of the CNARS as does the Pratt anticline and most late Paleozoic structures in the Sedgwick and Salina basins.

Information presented thus far then suggests that the older accretionary terrain influenced the location of the CKU and structures immediately west, while the younger CNARS was of major influence on Late Paleozoic-aged structures farther east such as the Nemaha uplift and ancillary anticlines.

I now will examine more evidence for recurrent structural movement in western Kansas and consider their possible effects on sedimentation.

7. LEFT 3-D DIAGRAM WS KS 8. RIGHT PRECAM CONFIG

A series of isopachs within the Permo-Penn interval are illustrated here as a series of block diagrams for western Kansas on the left screen. (LOCATION, NORTH, ASSUME TOP FLAT, NOTICE EXAG) The higher the colored upper surface of the block diagram, the thinner the interval. Some 2300 well logs were used in the construction of these perspective diagrams. The configuration of the Precambrian surface is shown on the right screen. The CKU-CA is very prominent as well as the Nemaha and [basins].

The three isopachs document the continued positive nature of the CKU, much like Rascoe has demonstrated for the Los Animas Arch

to the west. The most prominently expressed positive relief on the shelf is in the sediments that immediately succeeded the time of uplift. The variation in thickness was greatest during the early to late Pennsylvanian interval (BP to BKC). Nevertheless, even during the interval from Heebner to Stone Corral representing sediments deposited in excess of 25 million years since the major tectonism associated with the CKU, the this uplift was still expressed as a positive element on the shelf. The entire area was also being tilted southward toward the Anadarko basin.

LEFT STRUCT CORRAL 10. RIGHT TOP K ZONE

[loc, county, CKU outline, colors thickness in feet (bar scale) -- CKU is apparent on struct map of upper Penn unit] The Stone Corral structure forms a large bowl plunging N-NW upturned edges.

A second order polynomial surface was fitted to the structure top Stone Corral and was then subtracted from this original surface to produce a trend residual map.

9. LEFT 2ND ORDER TREND STONE CORRAL HOLD

The residual map now on the left reveals the local positive anomalies coinciding with the eastern CKU, CA, and strong SW positive area trends that succeed depos. of Stone C. include NE.

A 4th order polynomial surface was fitted to the more complex K Zone structure and subtracted from the original surface to produce another trend surface residual.

LEFT HOLD 11. RIGHT 4TH ORDER TREND K ZONE

After removing the regional trend, then the residual maps in

both cases reveal details of the local positive anomalies that are apparent. [Rush Rib and general def. of CKU; CA]

2ND VERTICAL DERIV CLOSEUP

HOLD

On the left screen is a portion of the 2nd vertical derivative aeromagnetic map shown earlier, focusing on central Kansas [note the location of Pawnee County]. This more detailed view of the aeromagnetic map when compared to the map on the right reveals the very close relationship between some local structures such as the faulted Rush Rib and the magnetic trends. Some of the discontinuities in the basement suggested here by aeromagnetics later became locations of fracturing, faulting or folding.

It might be expected that this movement may have had a measurable affect on sedimentation during the late Paleozoic. Movement during the late Pennsylvanian will now be illustrated with the aid of results from a study of the upper Pennsylvanian Kansas City Group in western Kansas.

12. X-SECTION

13. X-SECTION INDEX MAP

PALEOGEOGRAPHY LATE

PENNSYLVANIAN, WESTERN

MIDCONTINENT

LEFT CYCLE DEFINITION <<--14.-->

RIGHT

WELL LOG

The Missourian Kansas City group consists of cyclic carbonates and shales that were deposited over much of the Midcontinent shelf. Four cycles were examined in the western HALF of Kansas. I will examine evidence for structural relief developed at the time the Kansas City Group was v. deposited.

Each cycle consists of a transgressive limestone, followed by a marine shale, succeeded by a regressive carbonate, and finally a regressive shale. For purposes here the cycles or zones are referred to by the subsurface letter system: H (the youngest) Drum equivalent, I (Westerville-Cherryvale interval), J (Dennis Limestone), and K (the oldest) (equivalent to the Swope Limestone). The regressive carbonate is the dominant petroleum reservoir unit, representing a shallowing upward sequence of carbonate rock, frequented by high energy, porous facies at its top.

The first series of maps that follow portray the distribution of facies from the lower cycle, the K Zone, over western Kansas. Rather than the large intervals of strata examined to this point in the presentation, each cycle described here is estimated to have lasted only approximately half a million years or less and generally is under 100 feet in thickness. [Will specifically examine the thickness of the marine interval; maximum GR; porous carb]

LEFT ANNOTATED POLE MAP
counties CKU

RIGHT 15. K ZONE ISOPACH
4th order trend
surface and residual

The thickness of the marine interval of the K Zone, now on the right screen reveals pronounced thinning illustrated as hues of red which closely correlates with the CKU and Pratt anticline. Rush Co. thin here coincides with 4th order trend struct. residual [notice that thinning extends west of the CA defined by the truncated edge of the Miss] Furthermore, an arcuate-shaped thick shown here in dark blue in the southwest surrounds a thinned area which resides just east of the Apisipha uplift in SE Colorado. Notice also that the trends of the thicks and thins in the west, parallel the north-

western magnetic lineaments shown on the pole correction map on the left. Area of greatest rates of thickening to the south bordering the blue and green region also parallels the basement terrane. This is referred to as a zone of flexure or a hinge zone. So as the Anadarko basin was rapidly subsiding immediately south of this shelf area, this shelf apparently flexed along a line of preexisting weakness in the basement.

16. OIL FIELDS, WESTERN KANSAS

17. LEFT POROSITY TREND RIGHT HOLD

18. HAND CONTOURED POROSITY DISTRIBUTION

The thickness of porous regressive carbonate in the K Zone in excess of 5 feet generally corresponds with the development of oolitic grainstone facies across the southern shelf during K Zone deposition. A hand-contoured version of the thickness of porous carbonate is shown on the left slide which suggests the configuration of the lobes of oolite on the southern shelf. The hinge zone identified earlier defines the northern border of the thick oolite facies in southern Kansas. Notice a general northwesterly trend developed over most of the region west of the CKU with exception of a dev. around positive and fingers of θ CO a definite northeasterly trend in the southeast parallels basement structural elements associated with the CNARS.

14. LEFT GR MARINE SHALE RIGHT HOLD

Further confirmation that the structural configuration of the shelf affected sedimentation during the K Zone is provided by a map of maximum gamma radiation. Dark organic rich shales have gamma

radiation in excess of 150 API units related to abnormal concentrations of uranium. The accumulation of black shale here is thought to be related to the level of stagnation on the sea floor at the time this shale was deposited. This may in part be related to the water depth. Thus a map of the maximum gamma radiation shown here on the right may be interpreted to represent relative relief across the shelf, or at least variations in the level of stagnation. Note that in this map on the right screen the CKU, CA, and the positive area in southwest Kansas, are all identified by low gamma radiation in the marine shale. In these areas the gamma radiation is at levels of normal shales, ie. no uranium enrichment. Thus independent indications suggest that these areas were positive elements on the shelf during K Zone deposition.

Sedimentation during this one cycle is related to the structural configuration of the shelf.

Similar mapping and core description were made for three overlying cycles, the J, I, and uppermost H zone.

20. LEFT J ZONE LITHOFACIES

RIGHT 21. isopach J ZN
4th order
trend surface
and residual

The summary block diagram for the lithofacies distribution of the overlying J Zone (or Dennis Limestone) in western Kansas is shown on the left screen while the marine interval isopach is shown on the right. The hinge or flexure zone is now displaced further south identified here as the blue and green area on the right and is an area over which the oolite facies again is developed. The positive elements are all very similarly expressed as in the K Zone with

the exception of a more subdued SW positive. Furthermore there was no arcuate-shaped buildup of carbonate surrounding the SW region. Terrigenous clastics prograded across much of the NW shelf apparently following lower elevations.

22. LEFT I ZONE

RIGHT ISOPACH I
4th order
trend surface
and residual

[summary block diagram; marine interval isopach]

I Zone carbonate pinches out along the northern margin of the shelf into a red siltstone with well developed soil features. Furthermore the carbonate facies are overall more shallow water deposits across the entire shelf and there is ample evidence for subaerial exposure that eventually affected the entire region. The black shale facies in the marine shale is generally absent except in the extreme southern mapped area. Together this evidence suggests a shallower inundation of the shelf.

Structurally the shelf setting was still similar to the underlying two cycles, but the flexure or hinge zone on the shelf that resulted in pronounced thickening of the underlying two cycles was now displaced still farther south and the width of the positive CA was more substantial. Thus both structural setting and relative sea level were probably both important in producing a different facies pattern on the shelf than previously. The southern migration of the hinge zone may in part be the result of constructive progradation of carbonates to the south.

25. H ZONE BLOCK
DIAGRAM

24. LEFT H ZONE MARINE ISOPACH

26. MAXIMUM GR H ZONE

4th order trend surface and
residual

The isopach of the H Zone the uppermost cycle studied in the Kansas City Group is now illustrated on the left screen [blue thickest marine interval]. The maximum GR map of the marine shale of the H Zone is shown on the right (blues and green highest). The level of inundation of this shelf during the H Zone was greater than that interpreted during the underlying I Zone. However, the record of submergence is thought to be similar to the previous K and J Zones. For example, black shale was again common on the shelf and the regressive carbonate again extends appreciably into Nebraska.

Nevertheless, the marine interval of the H Zone is relatively thin over the entire shelf with additional thinning over a much broadened portion of the CA and particularly the extreme southeastern portion of the CKU centered over the white area on the left. Furthermore, the southwestern Kansas positive area was again active indicated by a broadened area of low gamma ray, thinned isopachs, and shallow water argillaceous lithofacies. In contrast to the underlying J and K cycles no flexure is recognized in this area of Kansas. Paleoslope is deemed to have been less during this cycle than during previous shelf inundations in the Missourian.

Therefore it is not surprising that there is a lack of widespread, thick oolitic facies especially along the southern margin of the study area. The shelf in western Kansas during the H Zone cycle was now generally a lower energy platform that was characterized by scattered micrite rich (low energy) carbonate buildups such as the phylloid algal mudbank noted in southern Rawlins and northern Thomas Counties. A much broader buildup some 50 by 100 miles in

extent indicated here on the left by the NW elongated blue region lies immediately northeast of the southwest positive area. The buildup may have developed here in proximity to the area which offered protection from the currents and waves originating from somewhat deeper water to the south. Further late stage shallowing resulted though in the development of local high energy deposits flanking the local positive elements on the shelf which in this case included both structural and sedimentologic features. [point]

The broadening of the positive area on the southeast and southwest and the lack of any other pronounced relief again demonstrate differences in epeirogenic movement on the shelf during the accumulation of each of these cycles. Yet the template of the underlying basement terrain is still evident.

27. LEFT PRECAMB STRUCT

RIGHT 28. KC ISOPACH

[outline, faults in blue, structural closure, sag, major anticlines]

The combined isopach of the four cycles is shown on the right screen. While gross interval isopachs show a close correspondence with the original outline of the CKU-CA, the differences observed from cycle to cycle are notable. The differences are not great in absolute terms, but the minor relief was of considerable significance when it came to defining what facies were deposited, their distribution, and the extent of diagenesis; three key elements of the distribution of petroleum reservoirs. **Epeirogeny and sedimentation are related!**

Nevertheless, these local subdued variations on the platform during these short term cycles generally follow the variations in the Precambrian terrain as expressed by the magnetic maps. The main

point to be made here is that it appears that indeed selected weaknesses in the basement were reactivated sometimes forming patterns closely resembling, but deviating slightly from the major uplifts. It was these trends that were important in establishing sedimentary grain. Thus during the accumulation of the Kansas City Group the shelf "creaked and flexed" responding to the stress transmitted by the rapidly subsiding Anadarko basin.

The style of deformation was controlled by the general template of the Precambrian terrain which in turn influenced local and regional depositional patterns.

(((CONCLUSIONS))))

LEFT SUMMARY SLIDE

Reactivation of structure and its affect on sedimentary processes can be carried one step further.

What about our contemporary land surface? Is this erosion surface affected by the underlying structure transmitted to the surface by reactivation of basement weaknesses? People exploring for buried traps of petroleum using satellite imagery would respond with a resounding YES.

The ideas of using surface structure to infer deep tectonism goes back many years. New technology has helped to access large volumes of information for processing and filtering to reveal and enhance elements significant to subsurface structural evaluation.

One such tool that will probably show continued promise in the future is computer processing of digital surface elevations such as the data base now available from the US Defense Mapping Agency.

Elevations on a regular grid spaced 63.5 meters apart are available on magnetic tape for Kansas and elsewhere.

LEFT TREND

RIGHT

The linear or 1st order trend surface residual map on the left and right have had the eastward sloping linear trend surface removed. It emphasizes local anomalies in the surface topography. This also facilitates comparison of locations across the mapped area. The earth's surface here is treated like a subsurface horizon, just as some of the buried layers which themselves represent unconformities. However, much more control is available to display the surface revealing much finer detail.

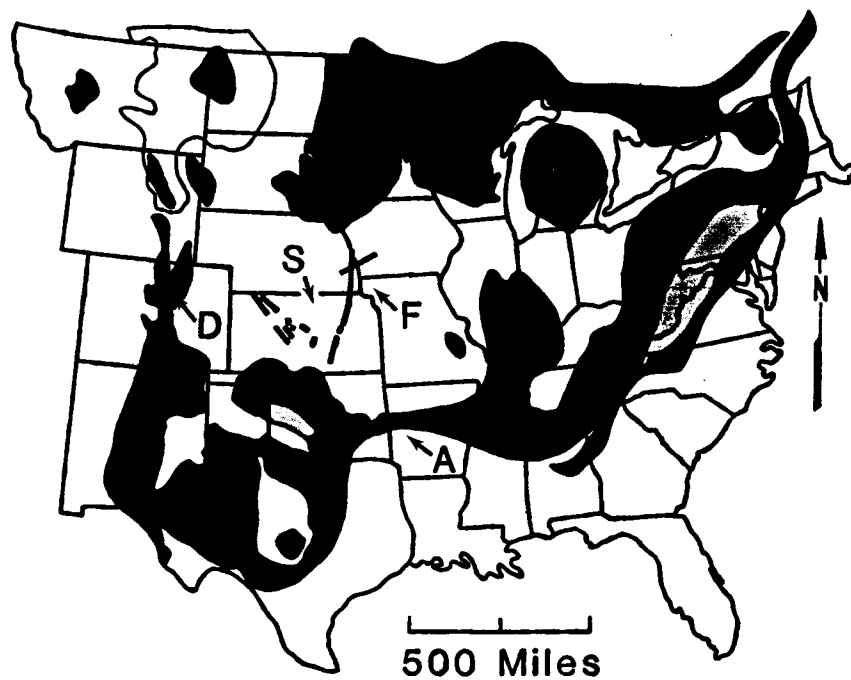
Notice the strong linear trends and the locally higher elevations. Much work has yet to be done with these maps to distinguish, for example, between surface outcrop patterns and subsurface effects. Yet, it is evident here that subsurface effects are apparent even with the cursory look given to this data thus far.

CONCLUSIONS:

1. Expression of tectonism is controlled by inherent weaknesses in basement.
2. Stress is directed into the craton during orogeny which many workers now conclude produced most of the major structures in a pulse of activity.
3. Yet, recurrent movement of these same structures varies episodically through time responding to weaker nonorogenic stresses having pronounced effects on sedimentation. [Numerous studies have demonstrated this.]

4. Moreover, geophysical methods like gravity and magnetics will continue to provide key information in interpreting structure and can be integrated with the basic framework of sedimentation.

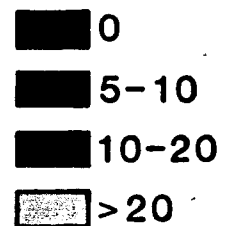
5. Finally, though only implied here, the remote sensing of the surface for regional and local structural information should continue to provide abundant evidence of the recurring structural activity over the Midcontinent.



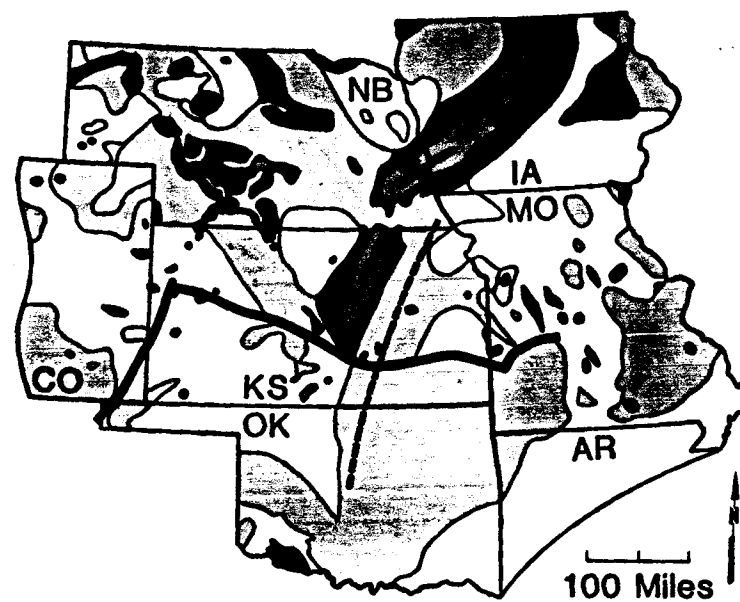
**PALEOZOIC BASINS
INTERIOR U.S.**

Contour interval:
1000 feet







- F Forest City
- S Salina
- D Denver
- A Arkoma



after Lidiak (1982)

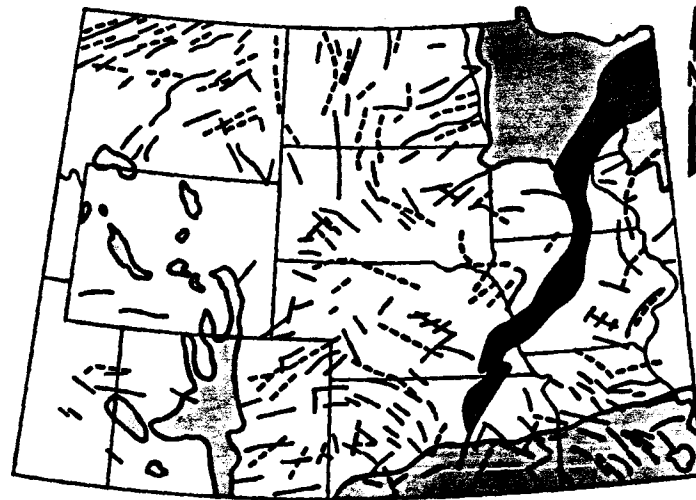


BASEMENT ROCK TYPES

-  Felsic
-  Granite, rhyolite
-  Gabbro, basalt
-  Metamorphic
-  Keweenawan sedimentary
-  Nemaha Ridge Fault Zone

after Bickford et al. (1981)

PRECAMBRIAN GEOLOGY AND GEOPHYSICAL TRENDS



--- Linear gravity trends

..... Magnetic trends

■ C.N.A.R.S.

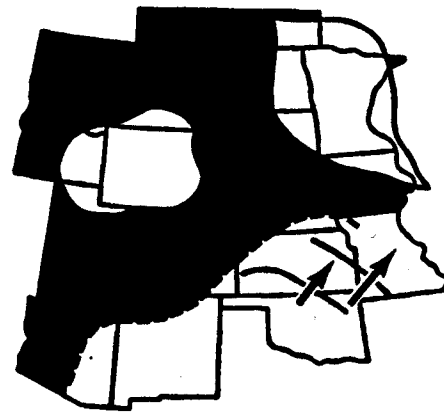
□ Rhyolite-granite terrain
(1500-1300 m.y.)
Bickford et al. (1981)

▨ Exposed
Precambrian Rock

┌──┐
100 Miles

from Dutch (1983)

ACCRETIONARY TERRAINS ACROSS MIDCONTINENT



TO:

North > 1700 m.y.

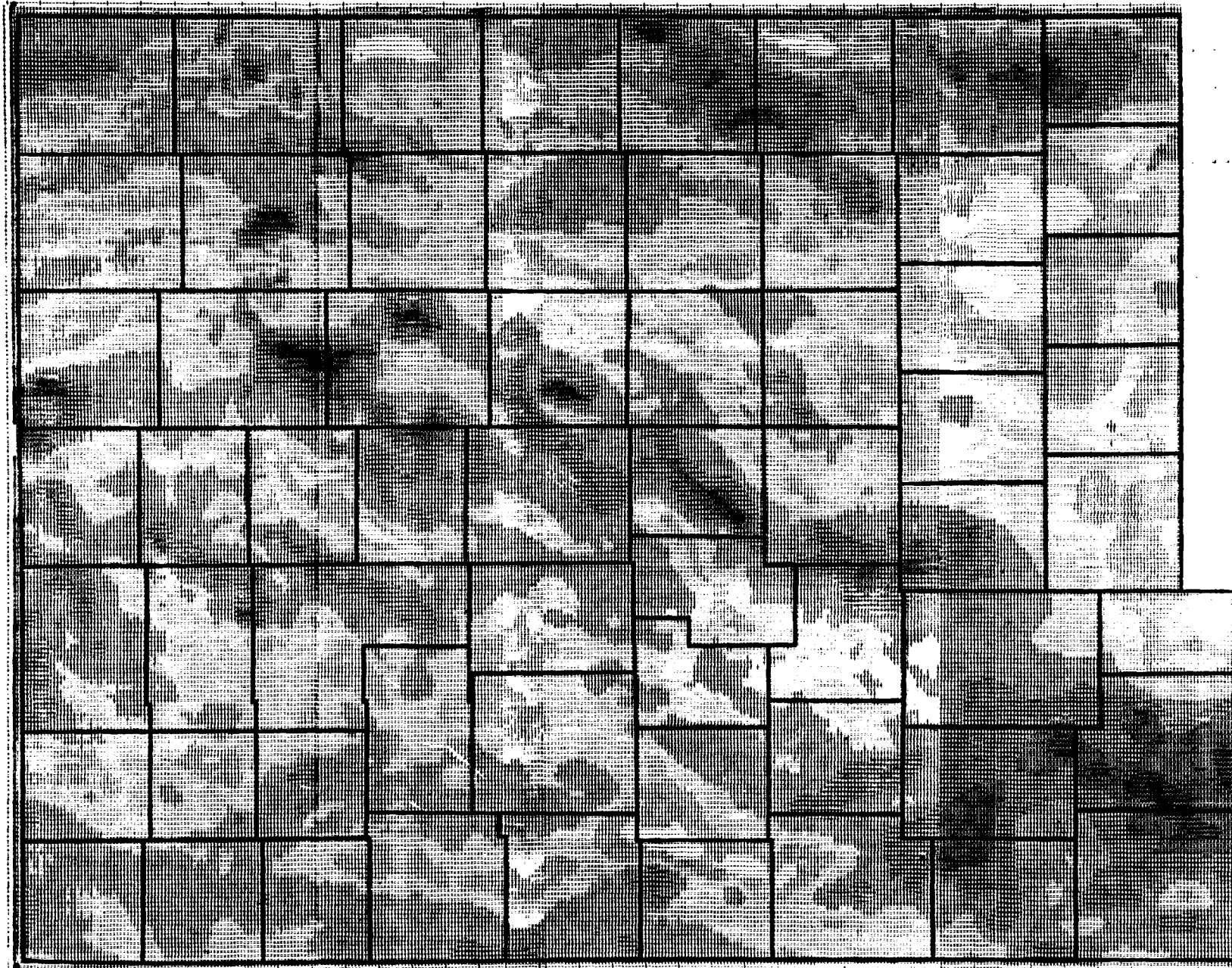
Southwest < 1700 m.y.

 Archean

 Accretion

after Dutch (1983)

Pole Correction Map of Magnetic Field (Yarger, 1965)



Precambrian
terrain boundary

NE trending
mag. line.

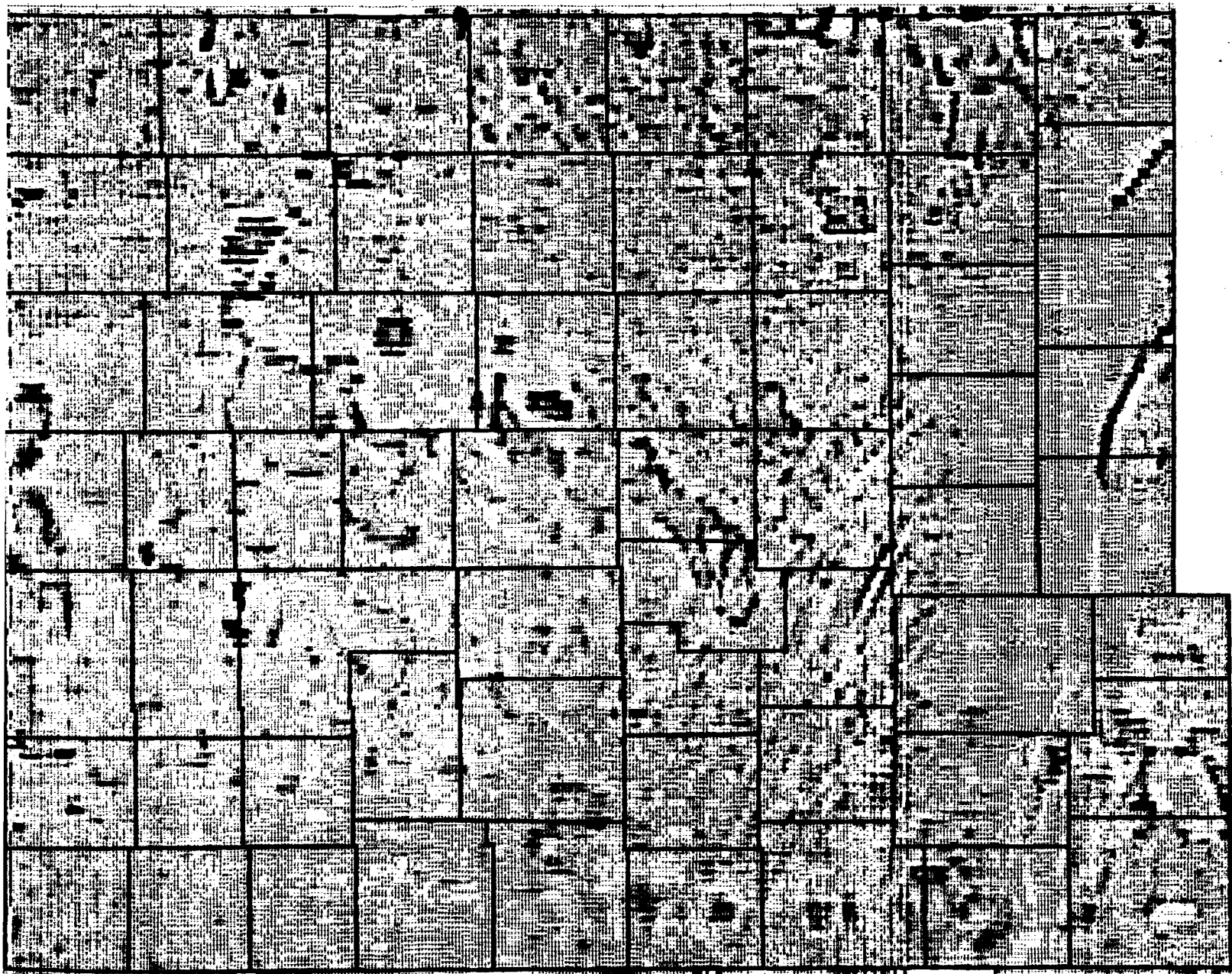
NW trending
mag. line.

basement faults

limits Central
Kansas Uplift

50 mi

2nd Vertical Derivative of Mag. Field (Yarger, 1983)

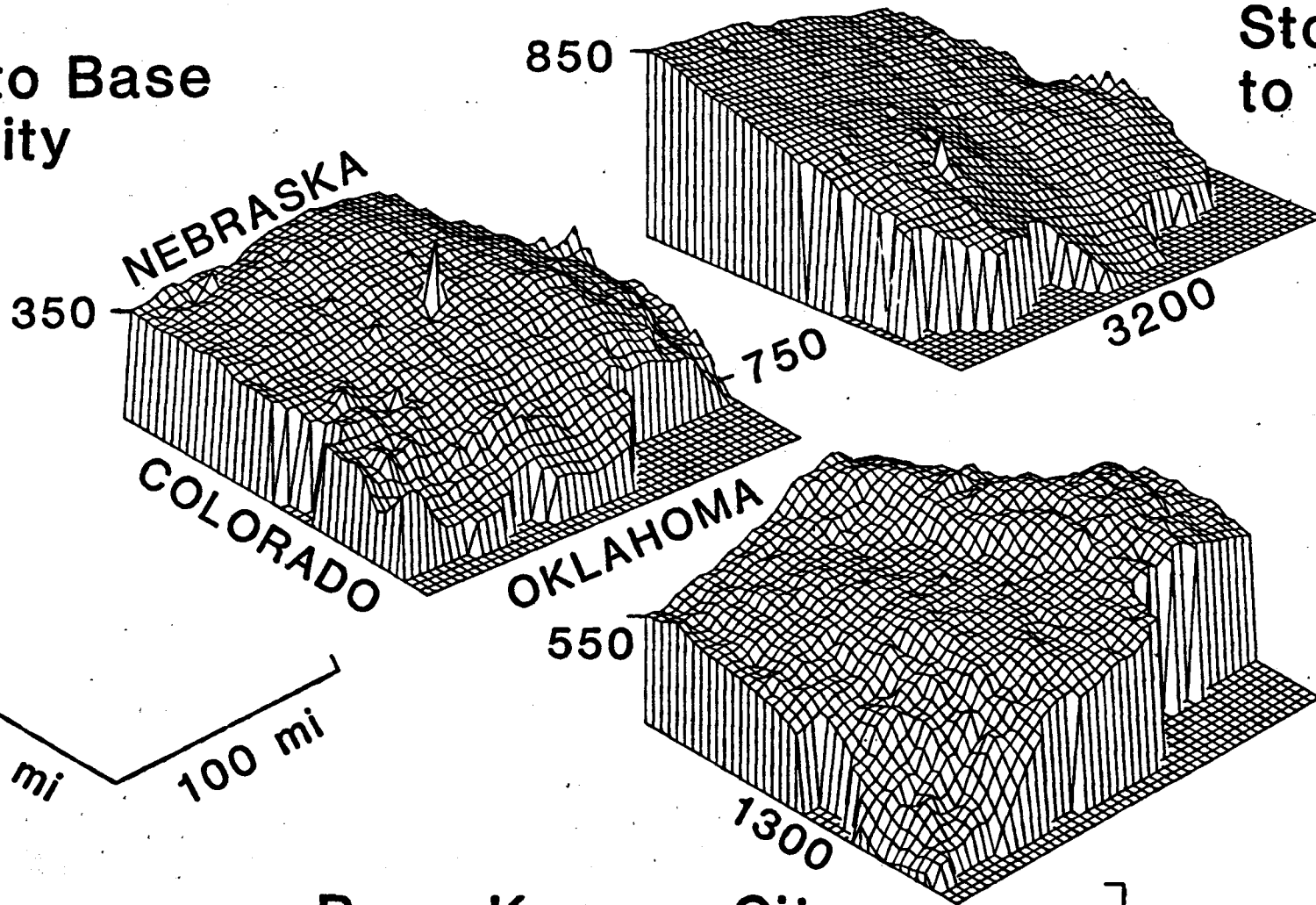


NE trending
mag. line.
limits
attenuated
mag. field
basement faults
limits
Central
Kansas Uplift

50 mi

⑥

Heebner to Base
Kansas City
Group



Stone Corral
to Heebner

1000 ft

most pos.



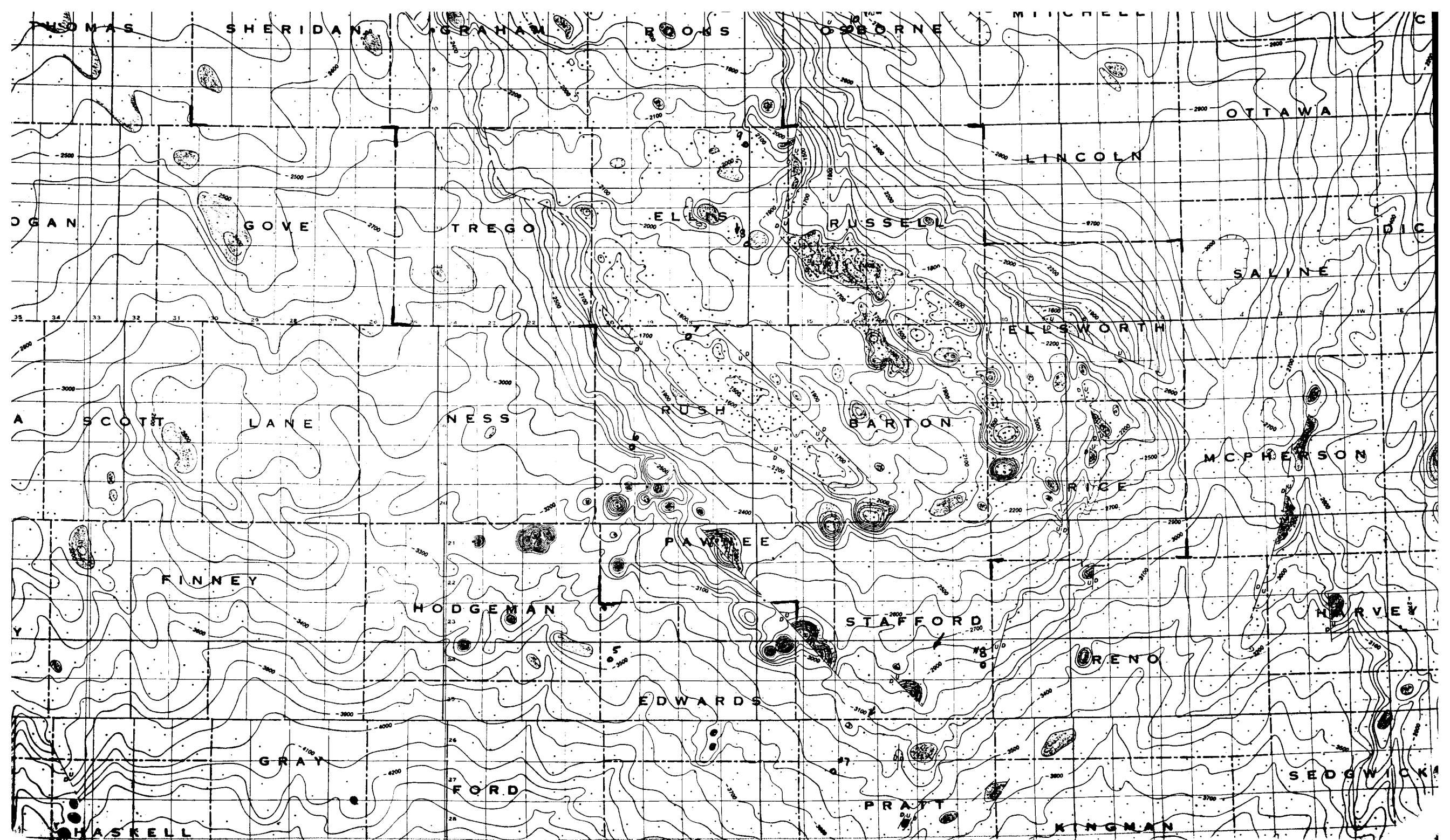
least pos.

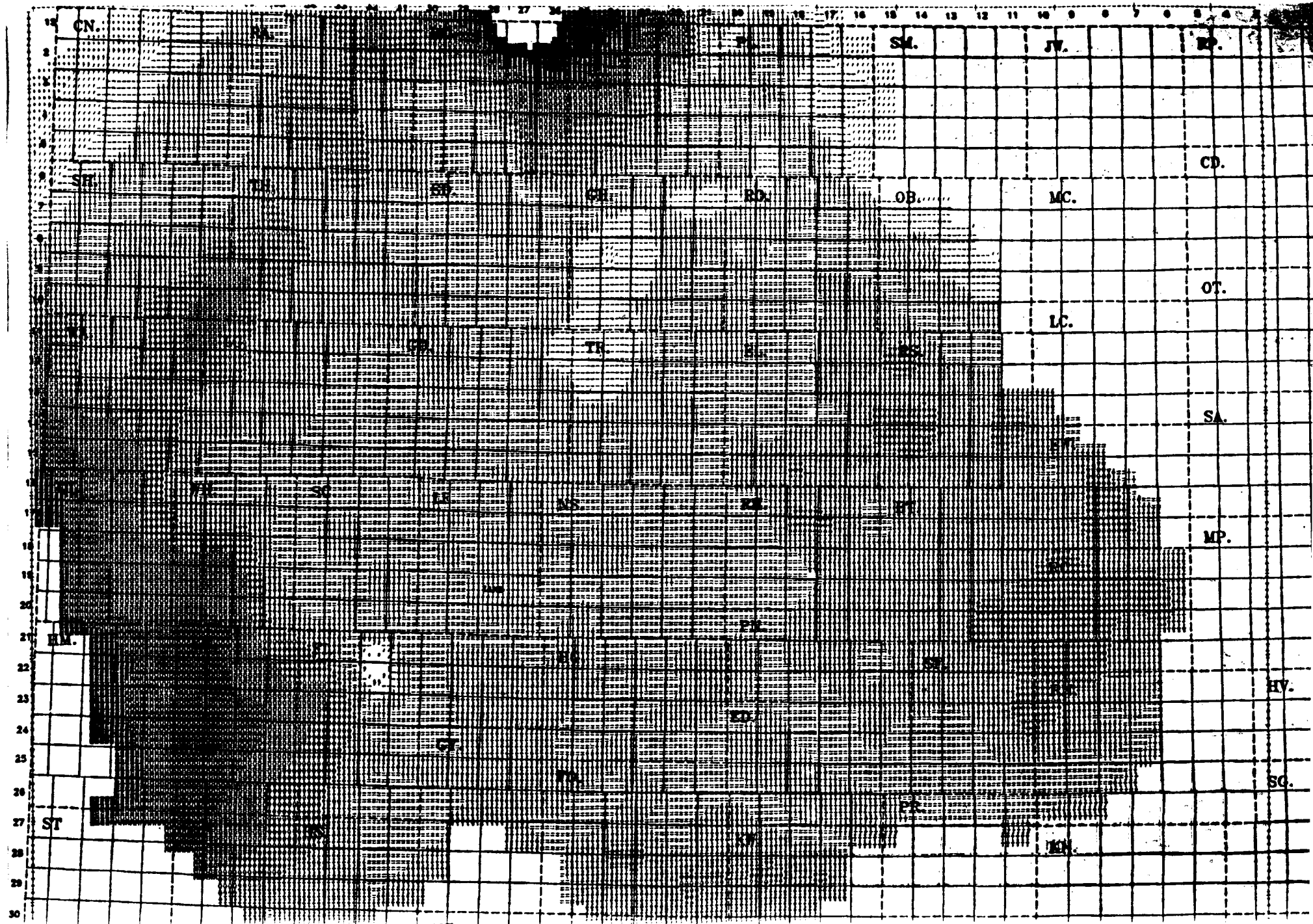
Base Kansas City
Group to Base Penn.

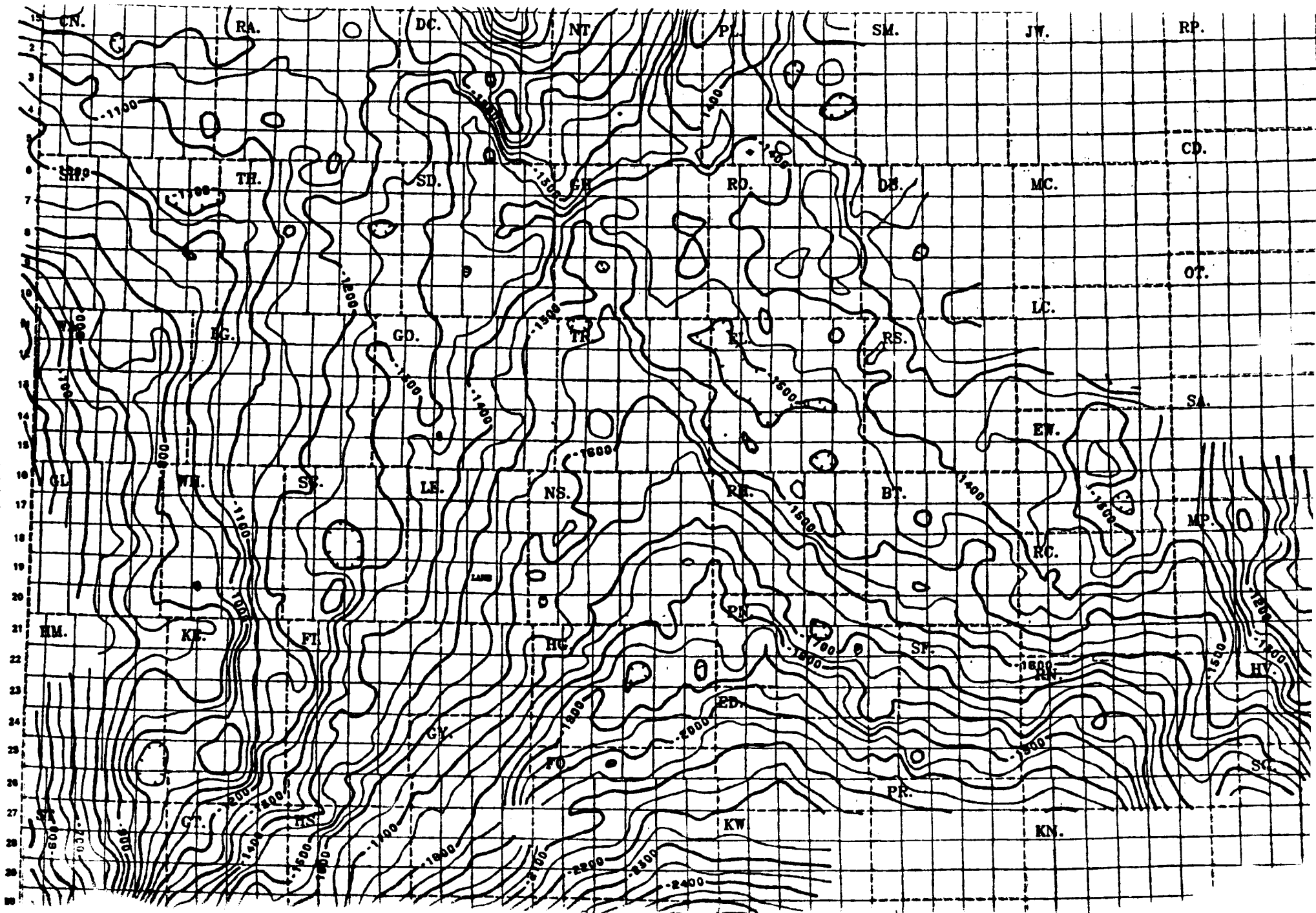
1000 ft

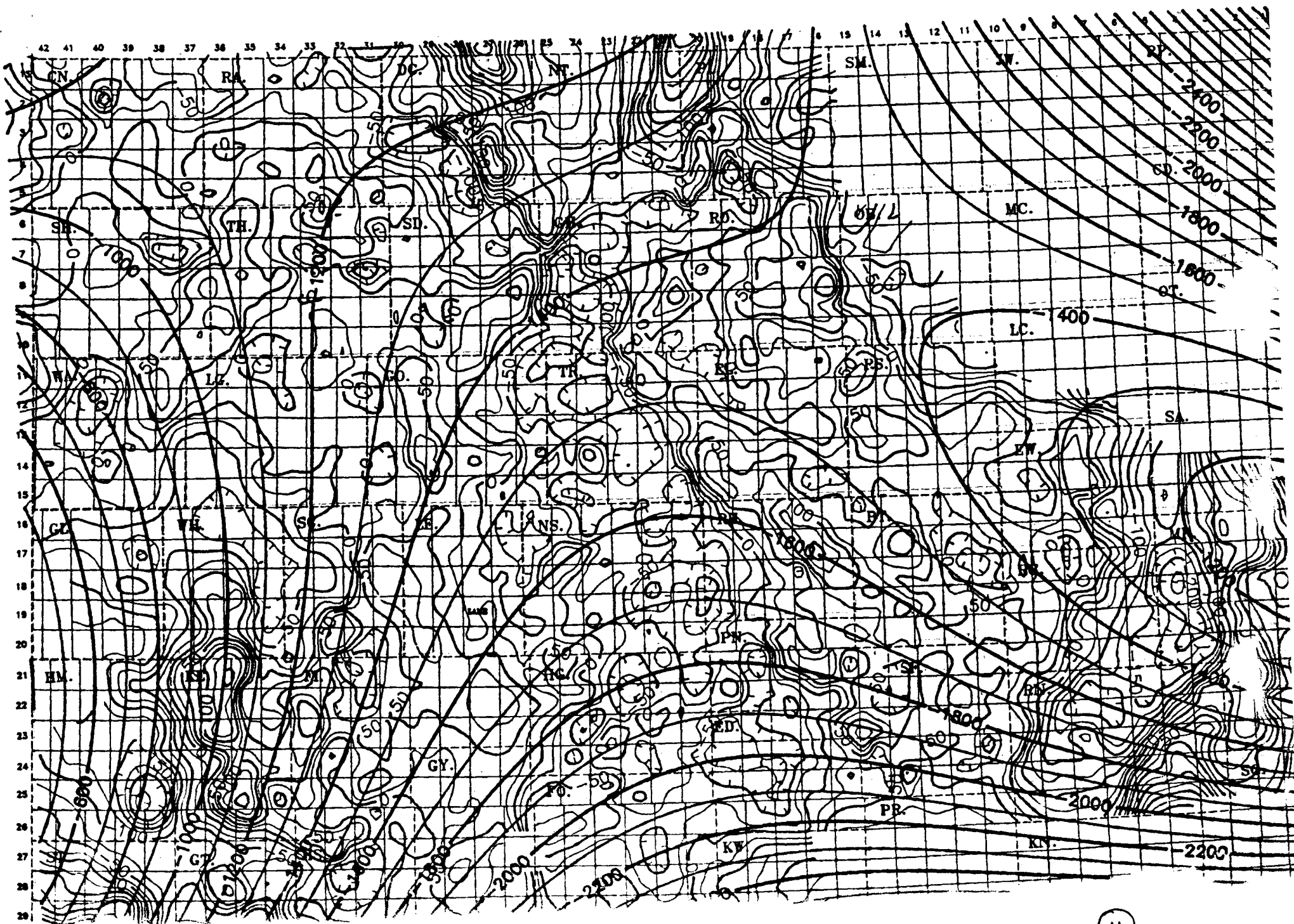
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Exag. 250x

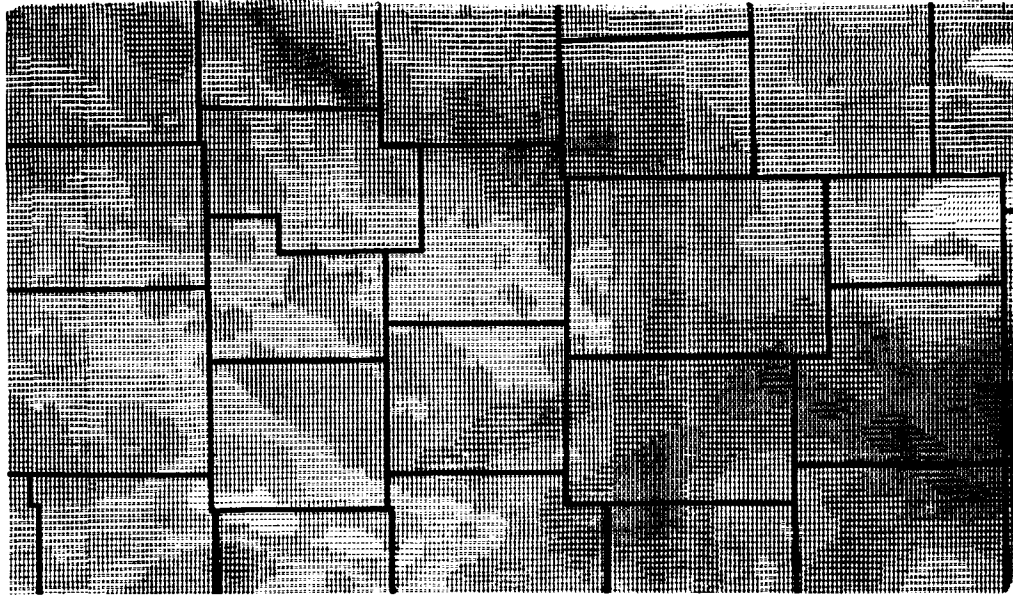








A. Pole Correction

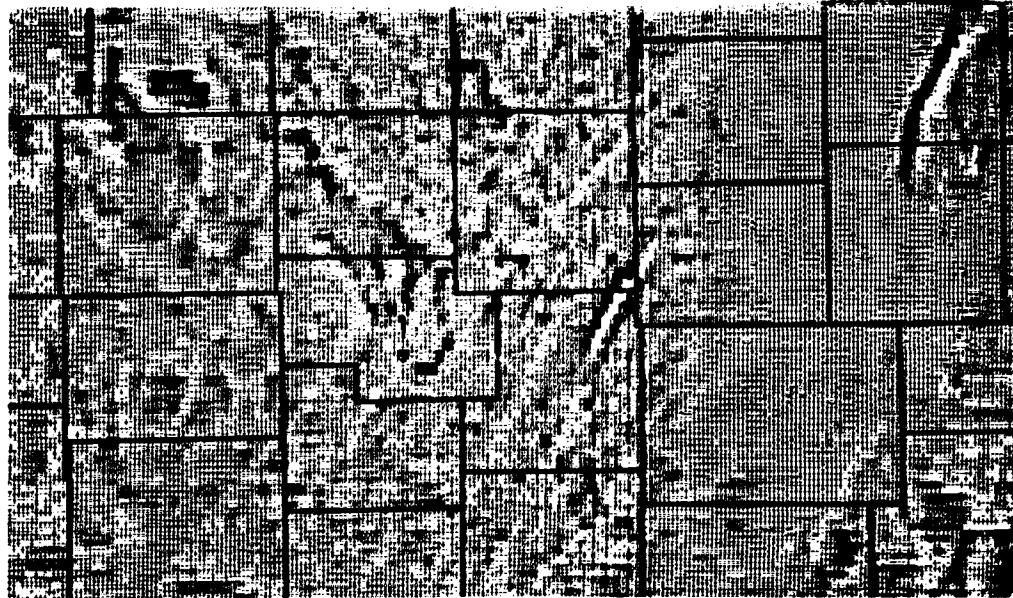


Precambrian
terrain boundary

NW trending
mag. line.

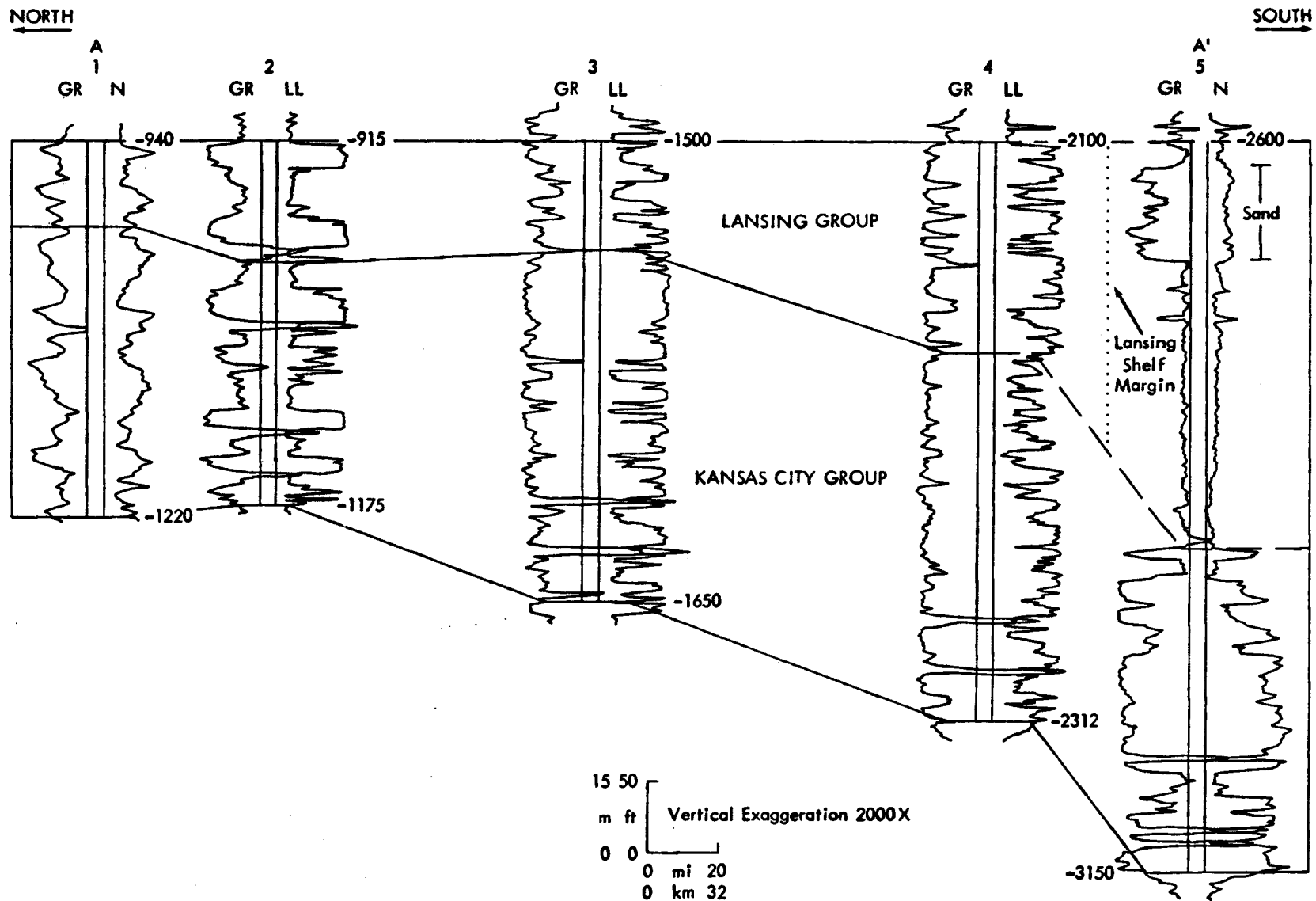
NE trending
mag. line.

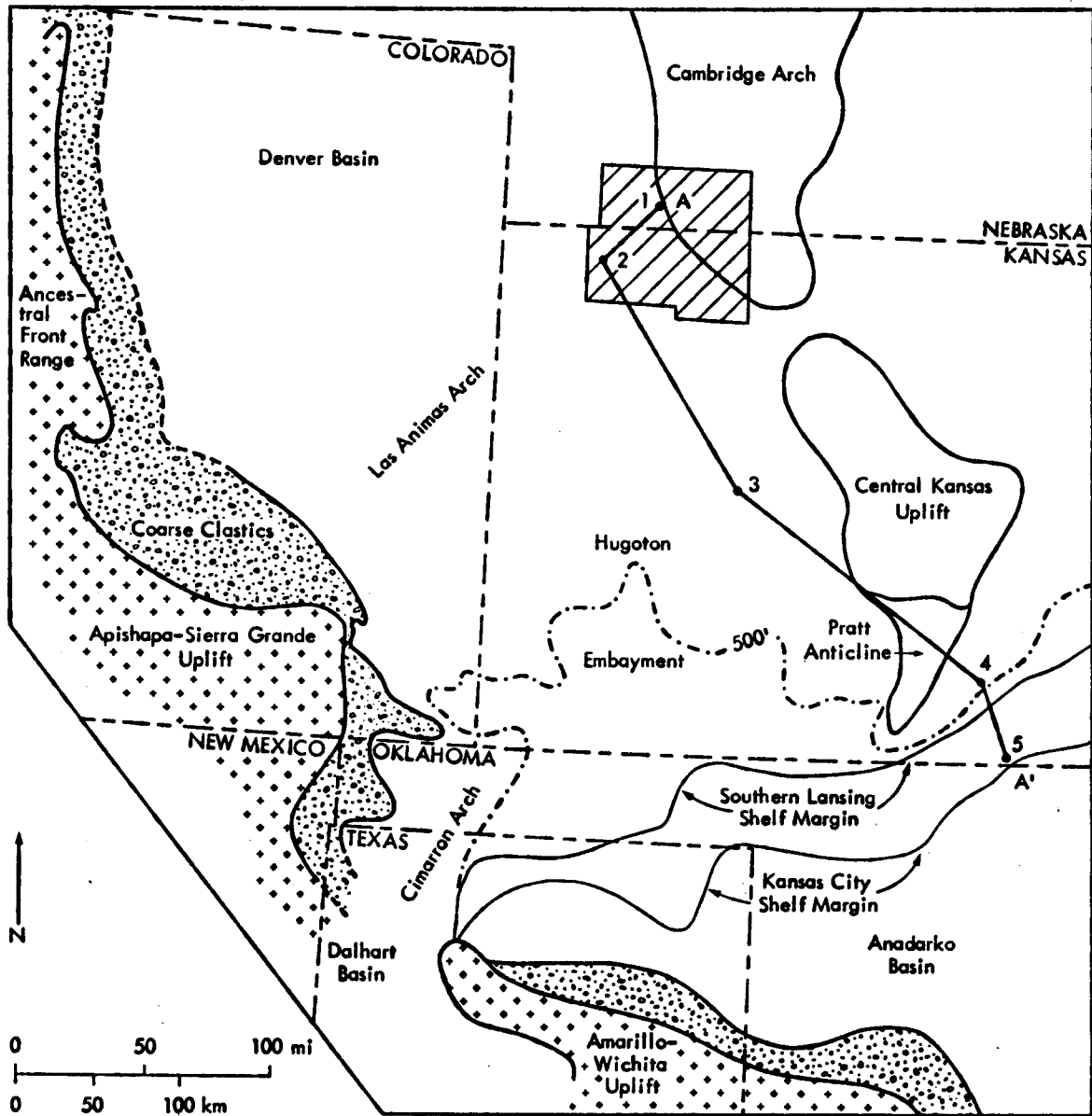
limits attenuated
mag. field



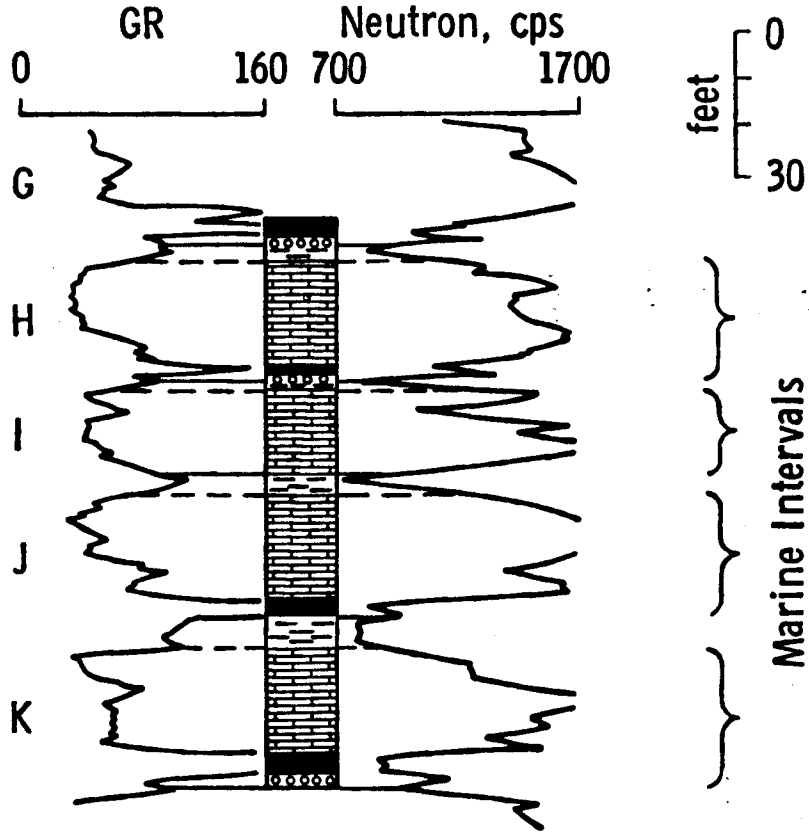
50 mi

B. 2nd Vertical Derivative







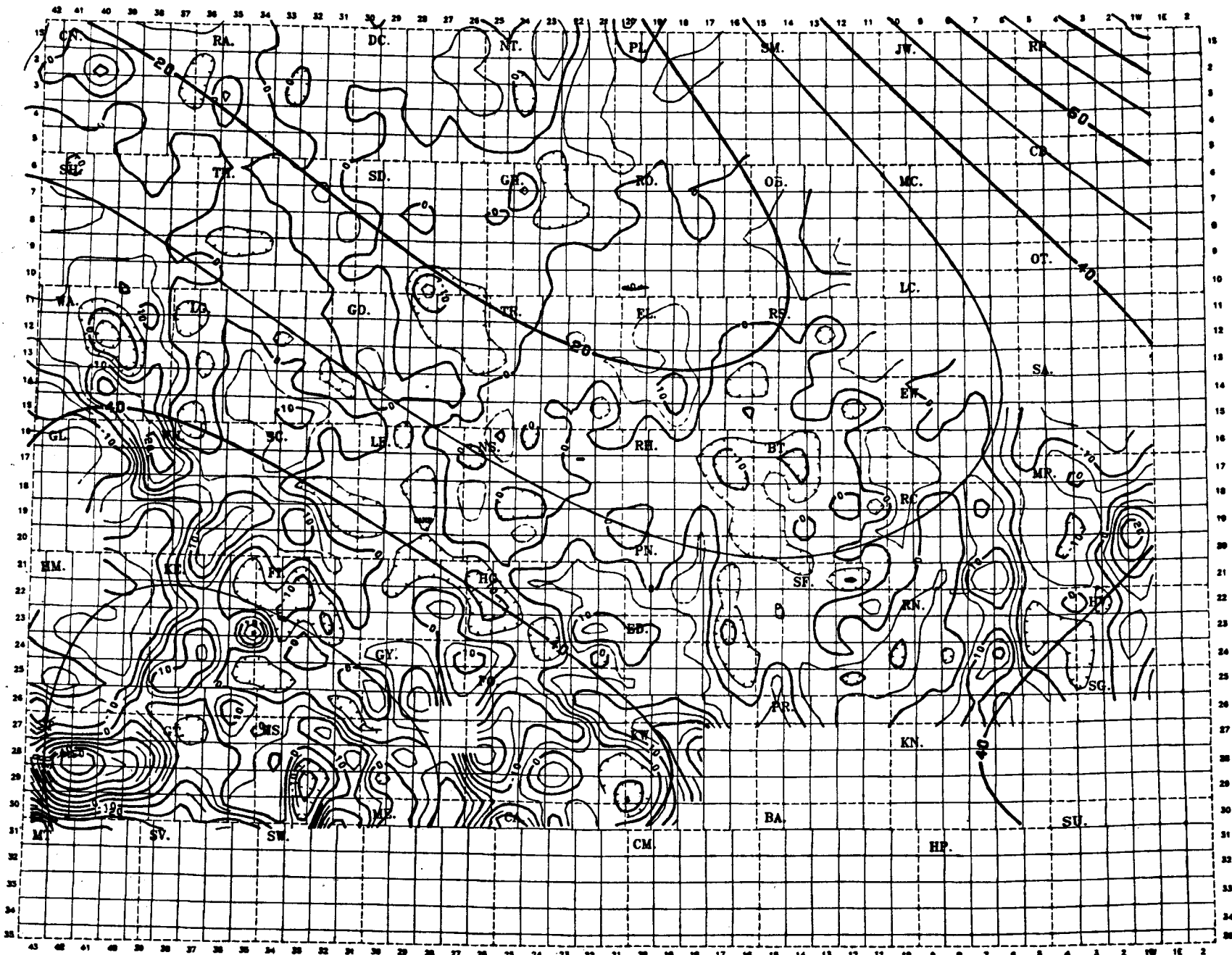


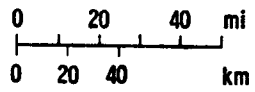
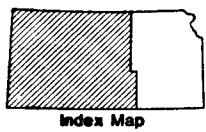
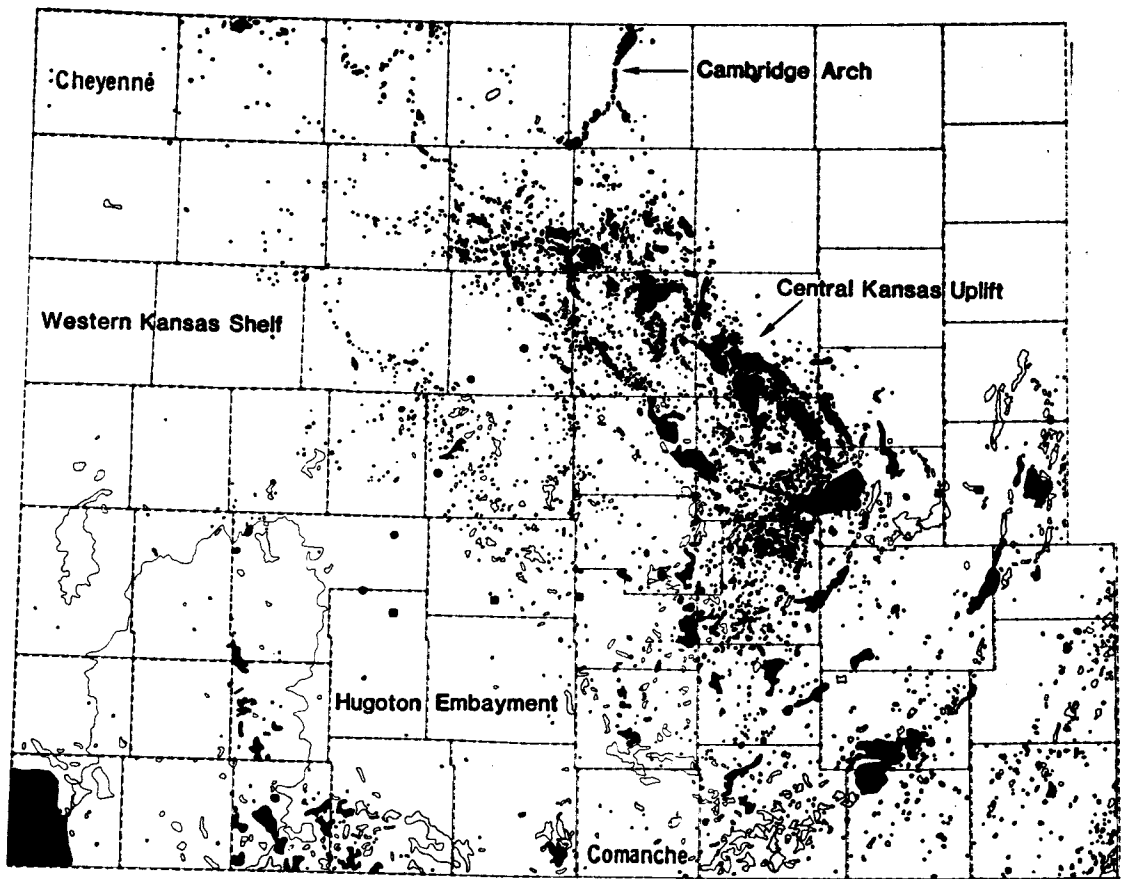
**Veail #1 Peterson
Sec. 7-7S-15W**

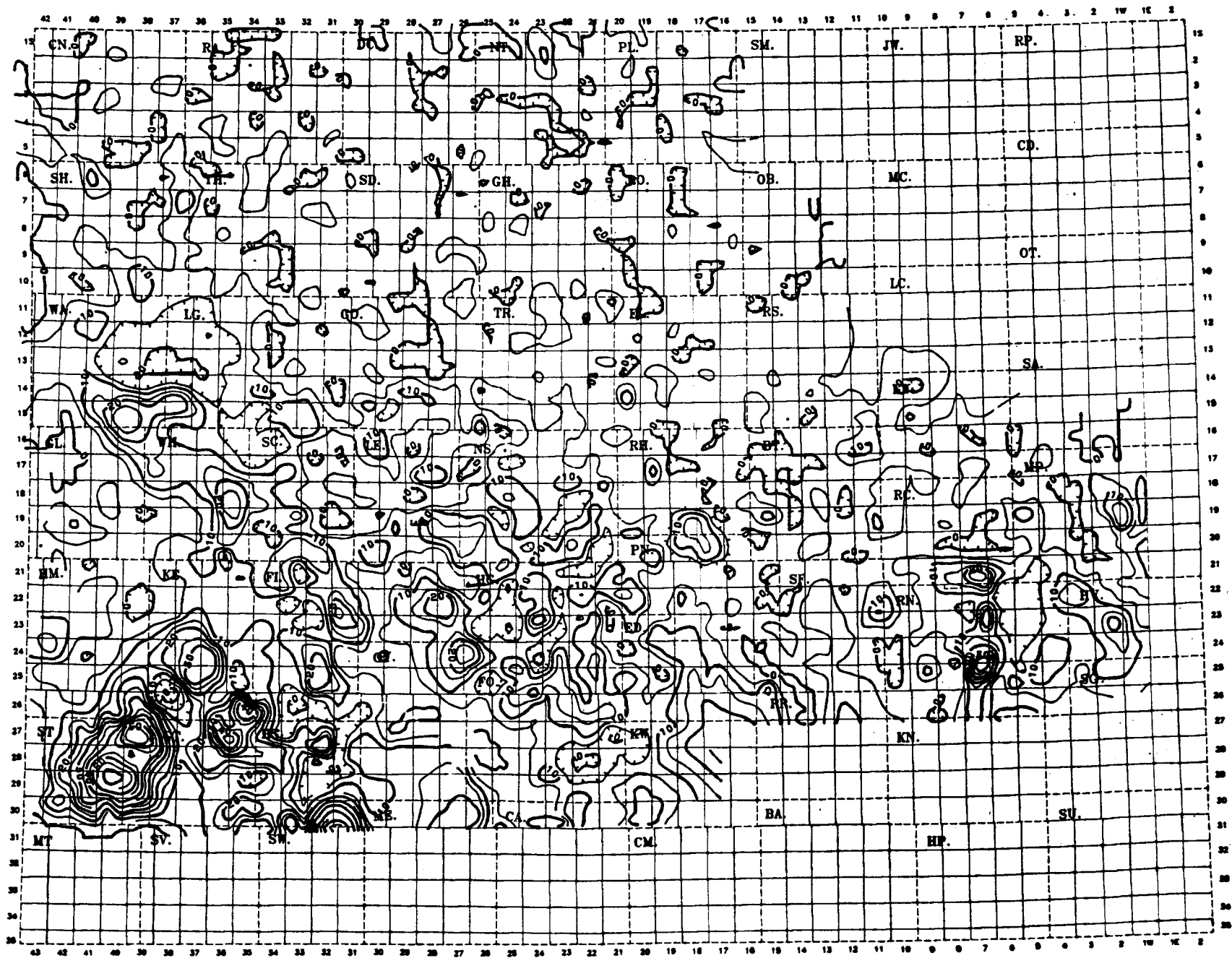


Sedimentary Cycle

-  Regressive shale
-  Regressive carbonate
-  Marine shale
-  Transgressive unit

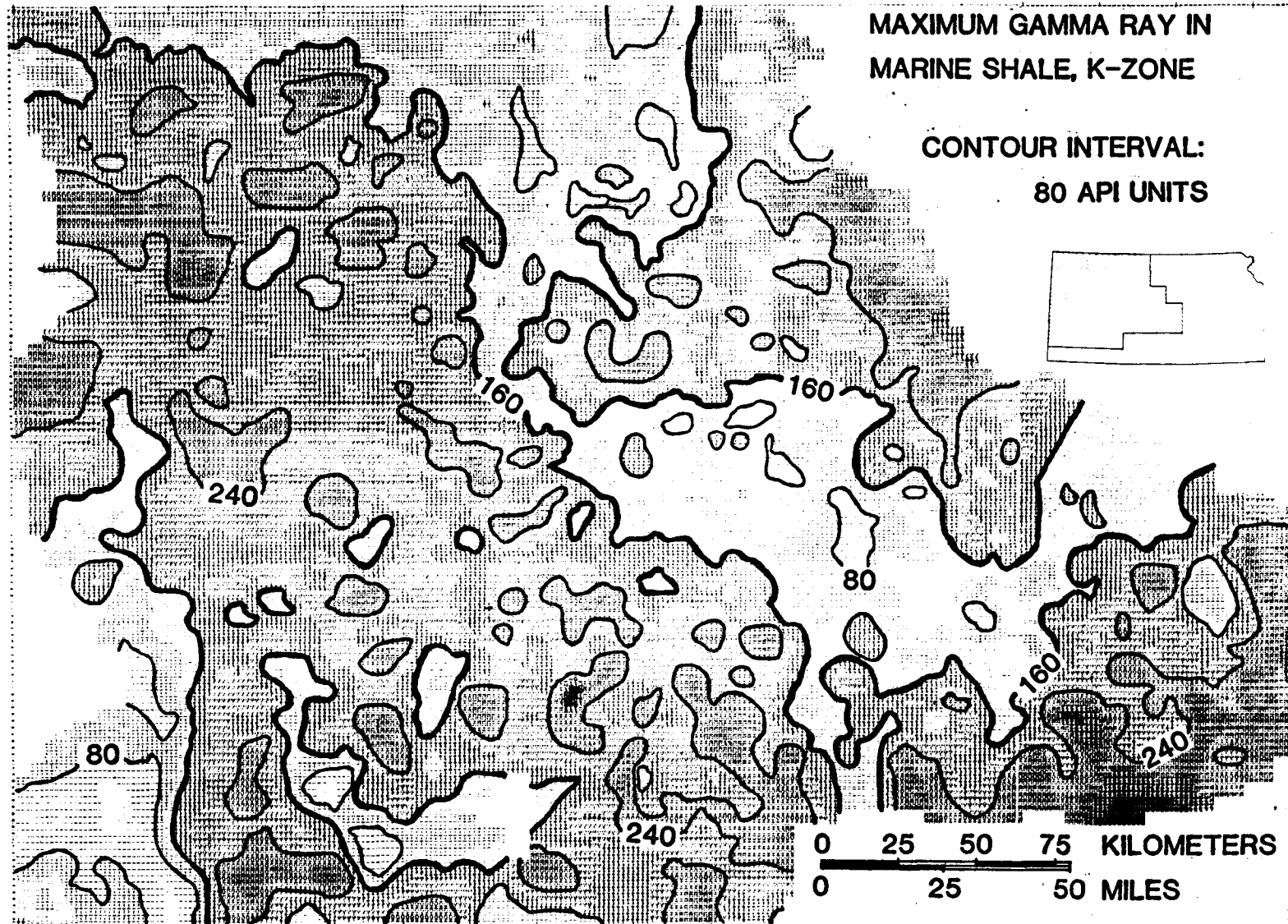




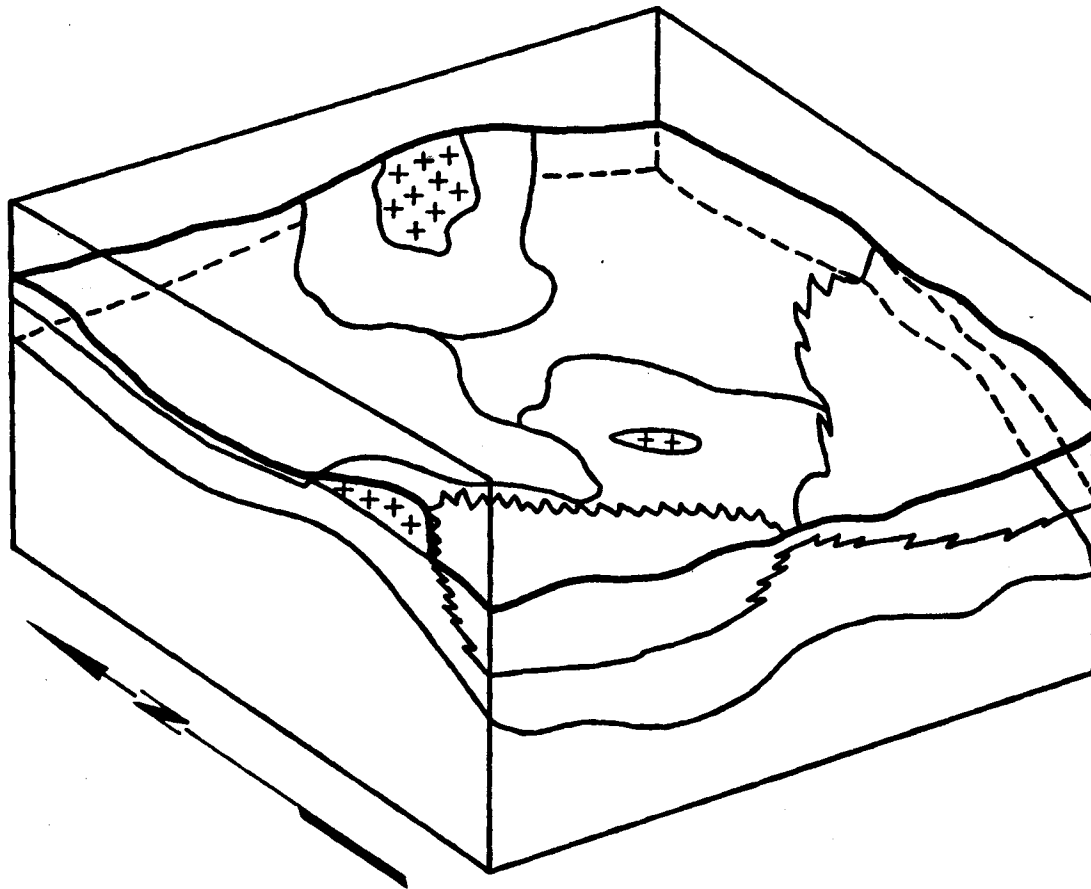


Thickness of Porous Carbonate K-Zone (Kansas City Group) Southwestern Kansas

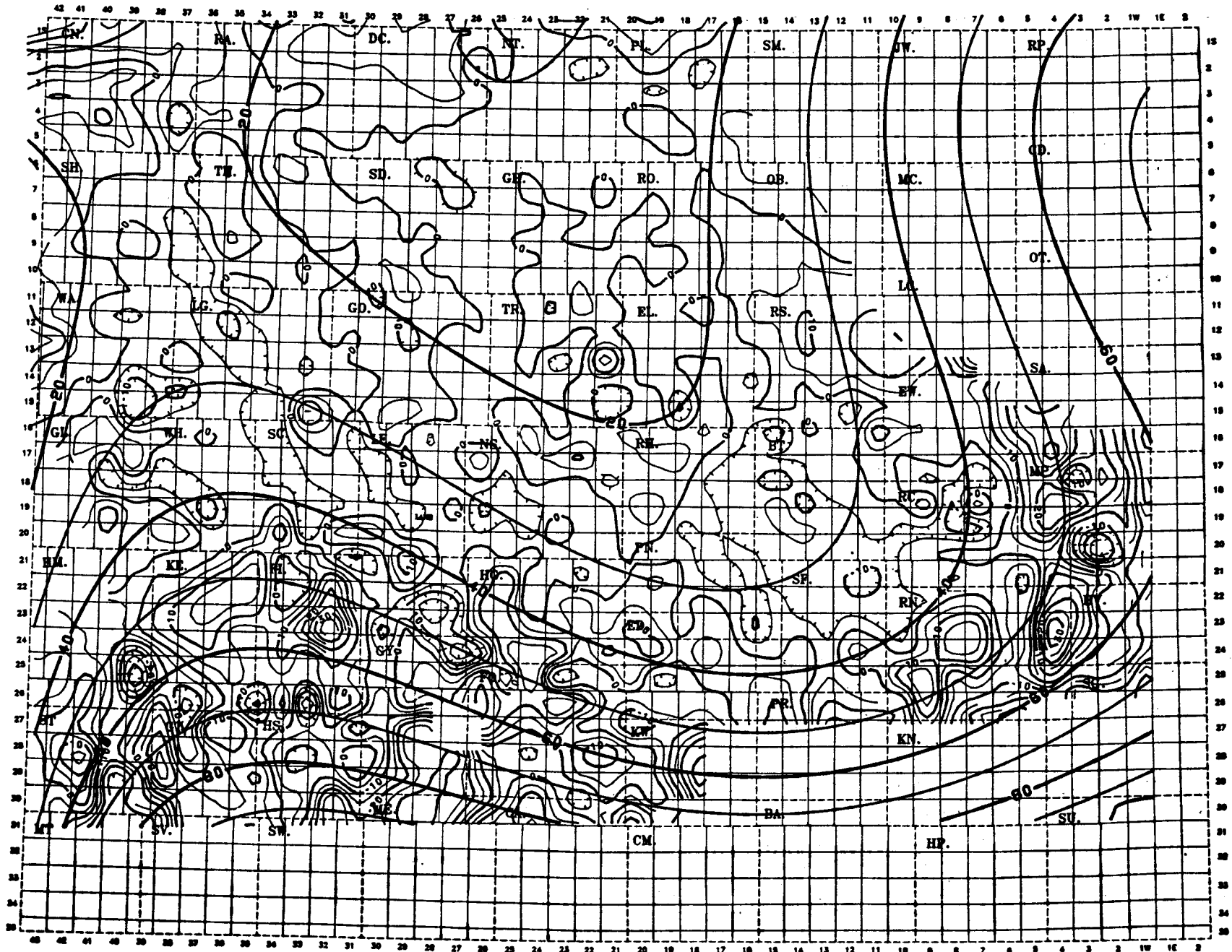




Lithofacies, Late Regression J-Zone (Kansas City Group)



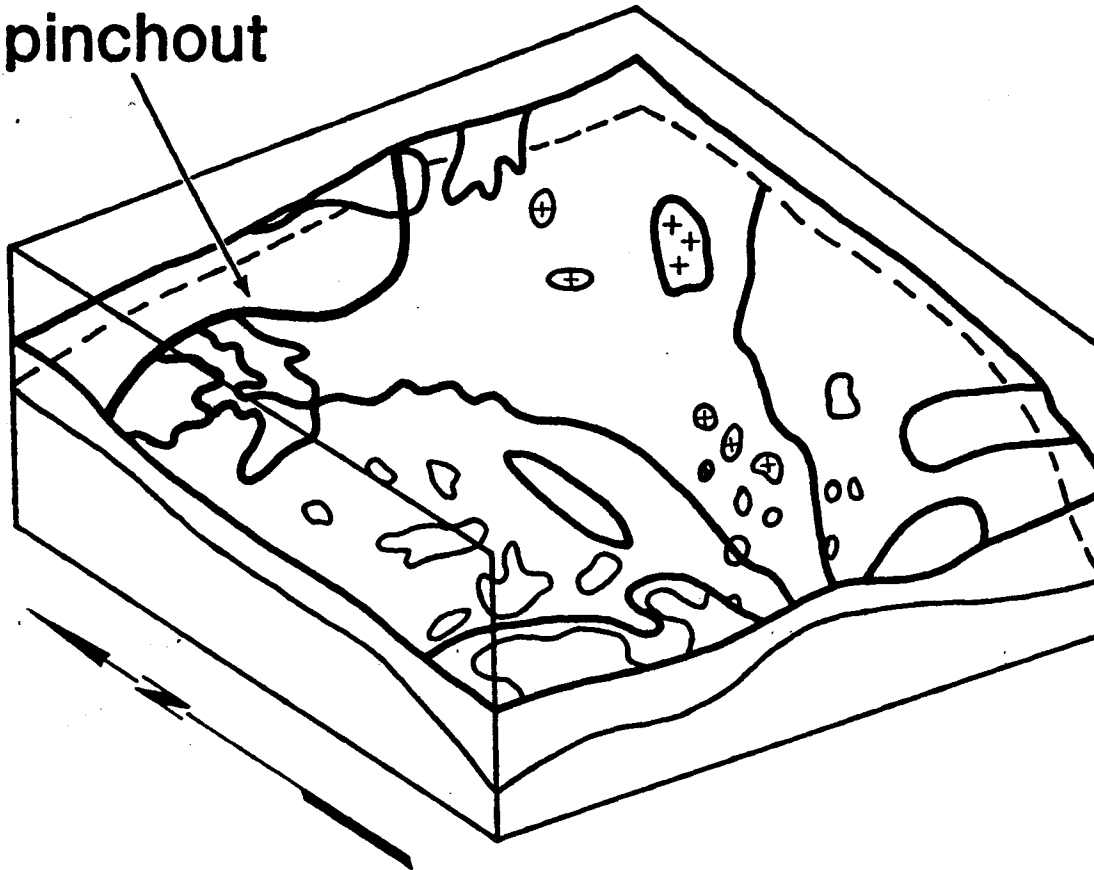
- Clastic wedge
- shallow water carb
- oolite
- most positive
- early emerg. carb. shelf




I-Zone (Kansas City) Shelf Configuration

Late regression lithofacies

pinchout



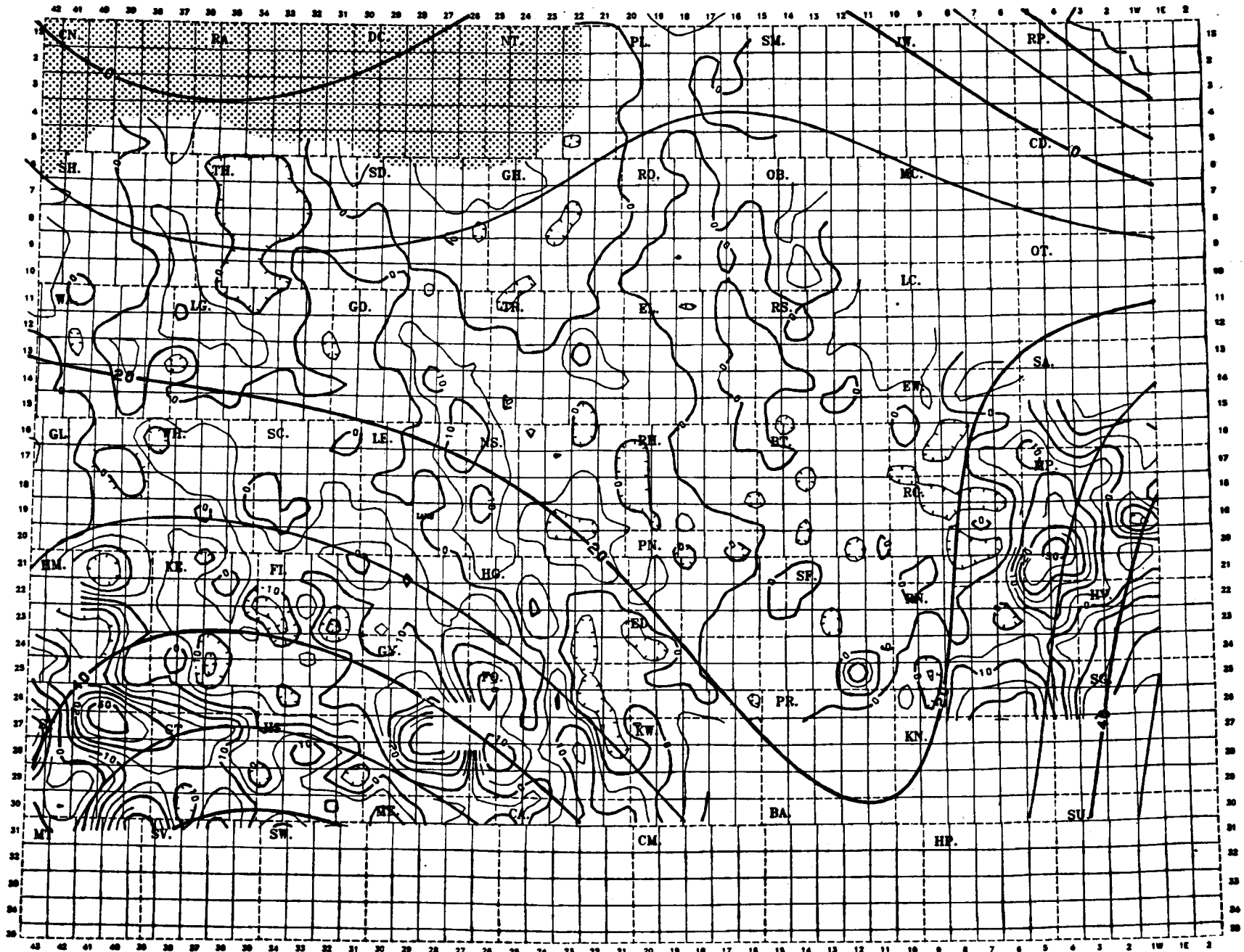
 most positive

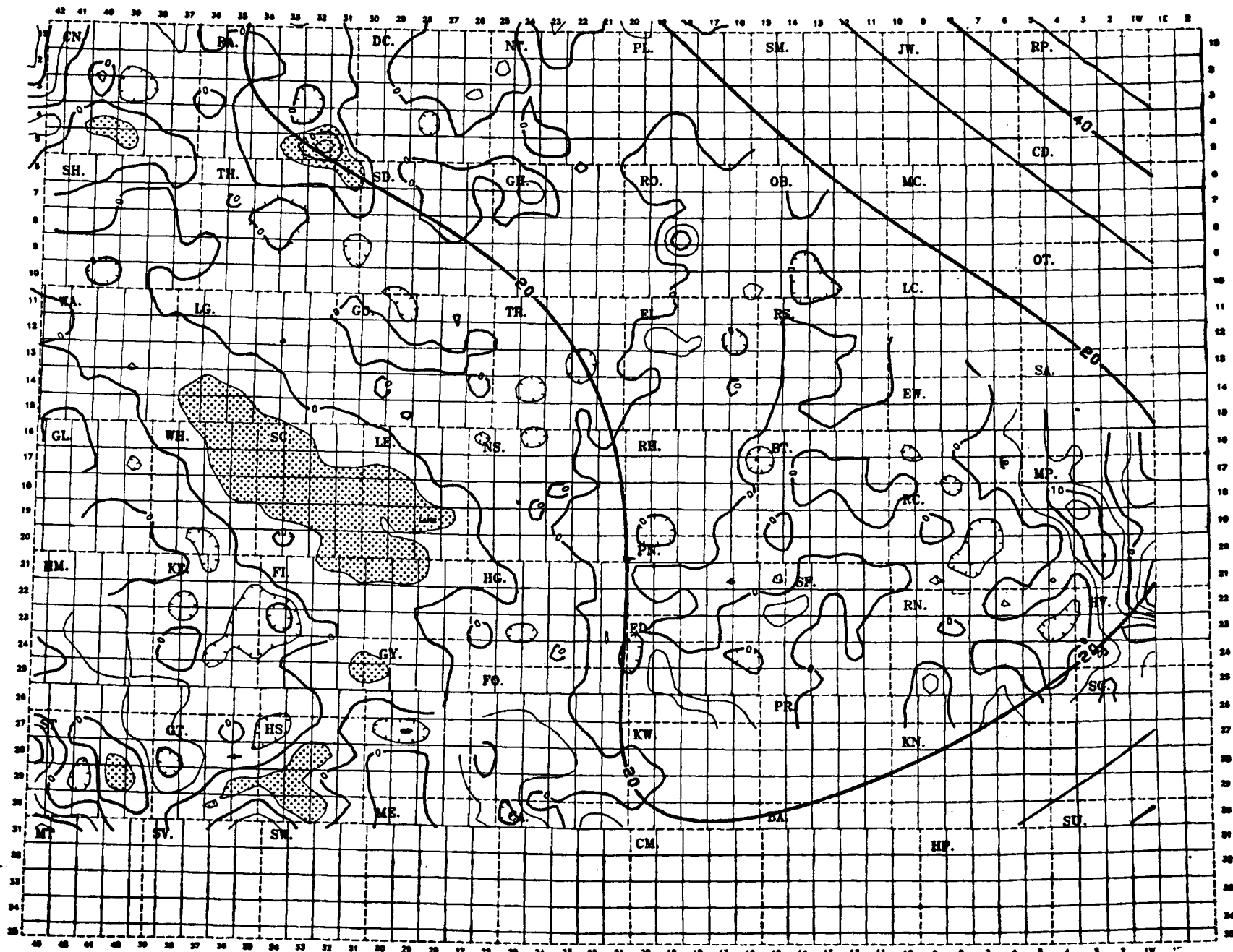
 early emerg.
carb. shelf

 thickened
shale lobe

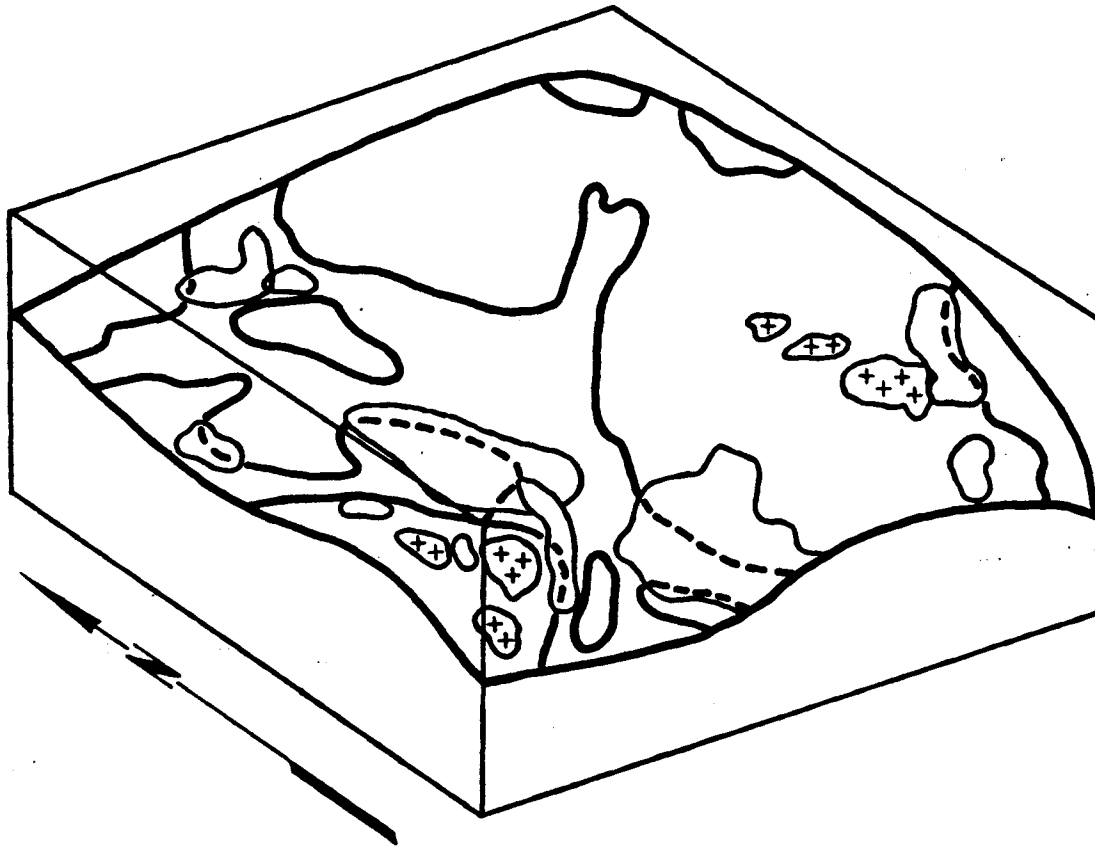
 porosity
thickness


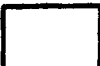
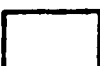

 flexure zone

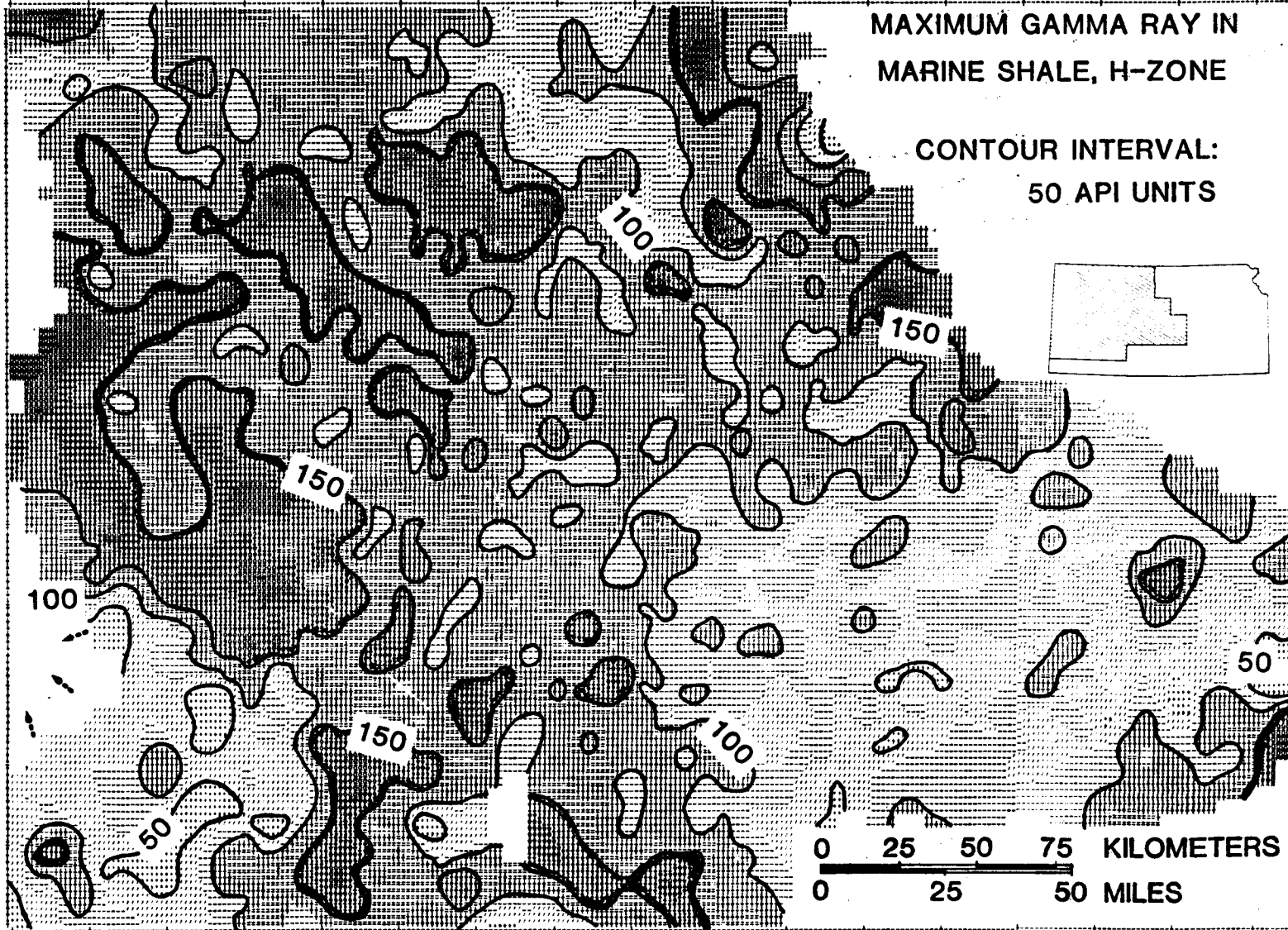




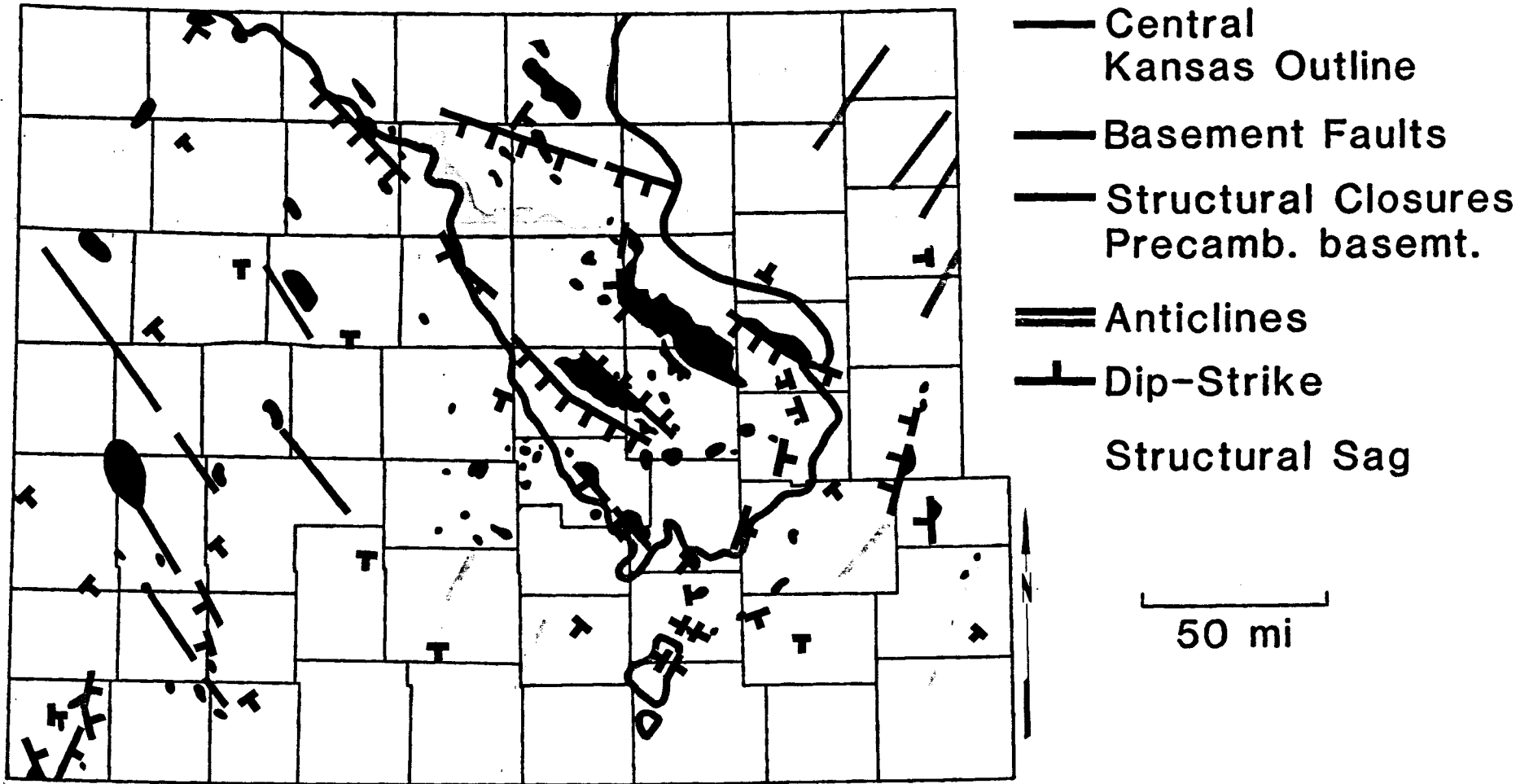
Shelf Configuration and Lithofacies H-Zone (Kansas City Group)

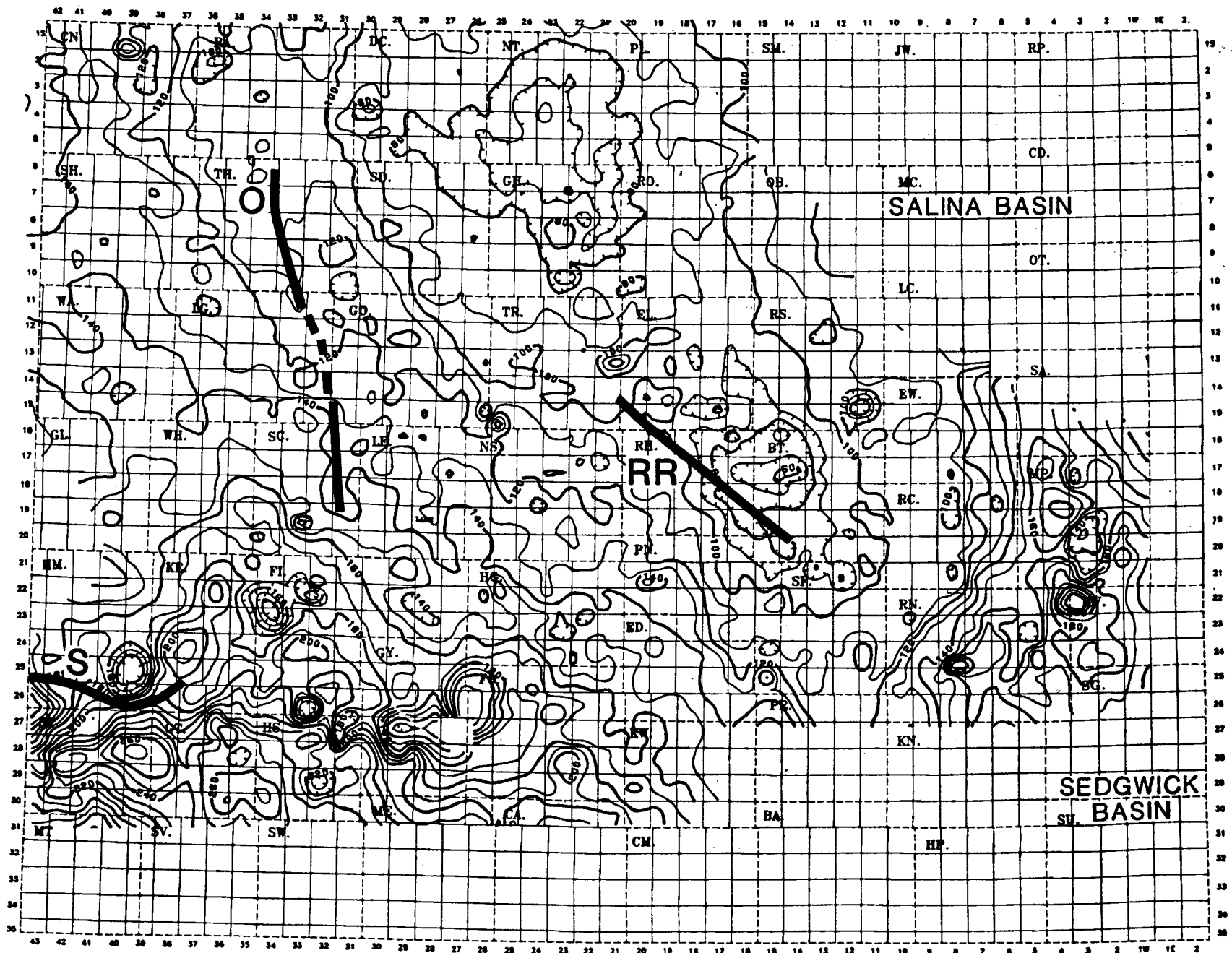


-  most positive
-  carb. buildup
-  early emerg.
carb. shelf
-  porous carb.



General Structural Setting in Western Kansas





Kansas Geological Survey
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