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Subsurface Geologic Study of the Hutchinson Salt

by

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SUBSURFACE GEOLOGIC STUDY OF THE HUTCHINSON SALT

THE OCCURRENCE OF SALT IN KANSAS WAS FIRST REPORTED BY ~~ROBERT HAY IN 1891 AND ERASMUS HAWORTH AND M. F. KIRK (1899)~~ well in 1887-98 gas in Rice Co., lead to opening of salt mine at Lyons Prof. George Swallow in 1866 in a preliminary report of the Geological Survey of Kansas.

N. W. BASS IN 1926 PUBLISHED THE FIRST REPORT REGARDING THE STRUCTURE, THICKNESS, AND LIMITS OF THE SALT BEDS IN WESTERN KANSAS. OTHER MORE RECENT REGIONAL STUDIES OF THIS SALT INCLUDE THAT BY ROBERT KULSTAD (1959) AND ROBERT SCHUMAKER IN 1966.

GEOPHYSICAL LOGS HAVE BEEN FOUND MOST USEFUL IN ACCURATELY DELIMITING SALT. THIS WELL LOG DATA BASE HAS GROWN CONSIDERABLY SINCE THE LAST STUDIES WERE MADE. THE OBJECTIVE OF THIS STUDY WAS TO EXAMINE THE ENTIRE HUTCHINSON SALT SEQUENCE IN KANSAS AND USING SUFFICIENT CONTROL TO BE ABLE TO DESCRIBE MORE LOCAL DETAILS OF THE SALT IMPORTANT TO USERS OF THIS INFORMATION.

I WILL BRIEFLY REVIEW THE STRATIGRAPHY OF THE SUMNER GROUP USING THIS REGIONAL STRATIGRAPHIC CROSS SECTION HUNG ON THE BLAINE MARKER. THE SECTION EXTENDS FROM WYOMING INTO WEST CENTRAL KANSAS. LET'S LOOK AT THE KANSAS ~~POSTURES~~ region OF THE CROSS SECTION.

THE HUTCHINSON SALT IS A MEMBER OF THE LOWER PERMIAN AGE WELLINGTON FORMATION WHICH IS DEFINED AS THE NONRED STRATA OF THE SUMNER GROUP. OVERLYING THE WELLINGTON FORMATION IN THE SUMNER GROUP ARE THE NINNESCAH SHALE, A REDBED UNIT, AND THE STONE CORRAL, PRIMARILY ANHYDRITE AND DOLOMITE WITH HALITE ALSO PRESENT IN SOUTH CENTRAL KANSAS. THE NINNESCAH SHALE IS, IN FACT, THE FIRST MAJOR

REDBED IN THE ENTIRE STRATIGRAPHIC COLUMN OF KANSAS. A RELATIVELY MINOR BUT SIGNIFICANT UNCONFORMITY IS PRESENT IN NORTHWEST KANSAS AT THE TOP OF THE NINNESCAH SHALE SEPARATING THIS UNIT FROM THE OVERLYING RUNNYMEADE SANDSTONE AND STONE CORRAL EVAPORITES. THE UNCONFORMITY SEPARATES THE UPPER FROM THE LOWER LEONARD STAGE AS DEFINED BY RASCOE IN 1972.

THE WELLINGTON FORMATION IS PRESENT IN THE SUBSURFACE OF THE WESTERN TWO THIRDS OF THE STATE WHILE THE HUTCHINSON SALT ONLY COVERS A PORTION OF THE AREA. THIS MAP OF OKLAHOMA AND KANSAS SHOWS A SET OF CONTOURS FOR SALT THICKNESS FOR EACH OF THE TWO AREAS.

THE KANSAS SET IS FROM A MAP FROM THE NEWLY RELEASED OPEN FILE REPORT OF THE SURVEY AUTHORED BY MYSELF AND SHIRLEY PAUL. THE OKLAHOMA MAP IS FROM A 1976 REPORT BY KEN JOHNSON.

THE SALT COVERS AN AREA OF 37,000 MI^2 IN THE SUBSURFACE OF KANSAS OCCUPYING A VOLUME OF SOME 1100 MI^3. THIS LARGE OVAL SHAPED SALT BODY REPRESENTS A DRASTIC CHANGE IN THE DEPOSITIONAL ENVIRONMENT FROM PREVIOUS CONDITIONS OVER THE CENTRAL MIDCONTINENT REGION.

THE STRATA OF THE EARLIER PERMIAN WOLFCAMP STAGE, REPRESENTED IN KANSAS BY THE ADMIRE-COUNCIL GROVE-CHASE GROUPS, ARE SIMILAR TO THOSE IN THE MIDDLE AND LATE PENNSYLVANIAN. THESE STRATA CONSIST OF CYCLIC CARBONATES, SHALES, AND SANDSTONES. THE WOLFCAMP AND OLDER PENNSYLVANIAN STRATA FURTHERMORE CONTAIN MOST OF OUR GAS AND OIL RESERVES FOR THE STATE OF KANSAS, ~~WHILE~~ THE LATER PERMIAN STRATA INCLUDING THE LEONARD ARE ESSENTIALLY BARREN OF HYDROCARBONS.

WHY DID THE EVAPORITES AND EVENTUALLY REDBEDS REPLACE THE HYDROCARBON-RICH, NORMAL MARINE AND COASTAL DEPOSITS OF THE PREVIOUS ERA? I'LL RETURN TO THIS QUESTION IN THE SECOND HALF OF THIS PRESENTATION. FIRST, LET'S GO INTO A DESCRIPTION OF SOME OF DETAILS

OF THE STRATIGRAPHY OF THE HUTCHINSON SALT IN KANSAS.

L. 3 Index map HOLD

ON THE left SLIDE ~~ON THE LEFT~~ THE HUTCHINSON SALT IS OUTLINED ON A MAP OF KANSAS. SOME MAJOR CITIES ARE INDEXED AS LETTERS, ALONG WITH SYMBOLS FOR THE LOCATIONS OF KEY CORES AND SALT MINES IN THE HUTCHINSON SALT. THE BORDER OF THE STUDY AREA AND LETTERS OF REFERENCE CITIES WILL BE INDICATED ON THE SUCCEEDING CONTOUR MAPS. BECAUSE THE SALT DOES NOT OUTCROP THE REFERENCE SECTION FOR THE UNIT HAS BEEN DESIGNATED TO A CORE TAKEN NEAR HUTCHINSON DESCRIBED BY C. L. JONES IN A 1968 USGS PROFESSIONAL PAPER.

THE HUTCHINSON SALT IS NOT A SINGLE SALT LAYER, BUT CONSISTS OF A SUCCESSION OF REPETITIVE INTERVALS OF GRAY-GREEN (REDUCED) SHALE, DOLOMITE AND MAGNESITE, ANHYDRITE, AND FINE TO COARSELY CRYSTALLINE AND LAYERED HALITE. (EG)

HOLD

GENERALLY, THE HALITE IS SEVERAL TIMES THICKER THAN OTHER LITHOLOGIES AS SHOWN IN THIS ILLUSTRATION. THE HUTCHINSON SALT IS IN THE BOXED IN AREA. THE GAMMA RAY, DENSITY LOG COMBINATION AND CORE GRAPHICALLY SHOWN here ~~ON THE RIGHT SCREEN~~ ARE FROM THE AEC #1 TEST HOLE LOCATED NEAR LYONS, KANSAS. THE 246 FOOT SALT SECTION OF THE HUTCHINSON IS WELL DEFINED BY THE LOW GAMMA RAY AND DENSITY SIGNATURES. NET SALT HERE IS 204 FEET. THUS, 83 PERCENT OF THE SALT SECTION IS HALITE. THE MECHANICALLY MINED SECTION OF THE SALT AT LYONS AND ALSO AT HUTCHINSON AND KANOPOLIS IS THOUGHT TO BE FROM THE SAME BED FOUND IN THE LOWER SECTION OF THE SALT.

Method of Study

The data base in this study consists of 3753 geophysical well logs, primarily gamma ray and neutron log combinations. The map area measures 42,000 mi^2. A goal of this study was to use 5 wells per township (36 mi^2) or one well per 7 mi^2.

The data recorded for each log were determined after a detailed grid of 10 N-S and E-W cross sections were constructed across the salt. These cross sections were then used as reference sections to compare with and correlate to during the compilation state. Data

L4 Entries HOLD

chosen for preparing maps include tops of major stratigraphic units such as the Stone Corral and Wellington along with the regularly spaced and correlable anhydrite and shale beds present throughout most of the salt. The marker beds are defined here as CM or correlation markers. A total of 20 entries were recorded per well.

L5 Entries HOLD

10 additional entries were added to each well by combining existing entries to make structural, isopach, and ratio maps.

HOLD Flowchart

The calculations are trivial while the number of calculations is large. It was decided early ~~on~~ in the project that computer processing was most feasible. Data processing, calculations, and contouring were done by computer using Surface II and Calcomp programs following a flowchart as seen on the right screen.

Data Presentation and Analysis

Intro Data Base Retrieval System

A series of maps and cross sections are now shown which describe the Hutchinson Salt in Kansas. On the left screen is an

INDEX MAP INCLUDING AN OUTLINE OF THE MAP AREA to be SHOWN IN THE SUCCEEDING CONTOUR MAPS. ON THE RIGHT SCREEN IS AN INTERVAL ISOPACH OF THE HUTCHINSON SALT ILLUSTRATED HERE WITH VARIABLE SHADING BETWEEN CONTOURS. THIS interval isopach MAP DEMONSTRATES A UNIFORM SHAPE TO THE DEPOSITIONAL BASIN WITH THICKENING TO THE SOUTH FROM LESS THAN 50 FEET ON THE NORTH TO OVER 500 FEET IN THE SOUTH CENTRAL MAP AREA.

THE MAP ON THE LEFT IS also AN INDEX MAP FOR TWO STRATIGRAPHIC CROSS SECTIONS.

THE N-S CROSS SECTION B_1-B_4 COMPOSED OF GAMMA RAY-NEUTRON LOGS EXTENDS SOUTH THROUGH THE CENTER OF THE SALT. THE DATUM OF THIS STRATIGRAPHIC CROSS SECTION IS THE WELLINGTON MARKER. AT THE TOP OF THE SECTION IS THE STONE CORRAL AND AT THE BOTTOM IS THE CHASE GROUP. THE SALT OUTLINED IN PURPLE THICKENS TO THE SOUTH AS DOES THE OVERLYING SHALE SECTION. THE NORTHERN PINCHOUT OF THE SALT REPRESENTS A FACIES CHANGE TO SHALE , I.E., DEPOSITION EDGE OF THE SALT. NOTE THE CONTINUITY OF THE ANDYDRITE-SHALE MARKERS WITHIN THE SALT SECTION RECOGNIZED AS spikes ~~SHARP KICKS~~ ON THE NEUTRON and/or gamma ray LOG AND THE SOUTHWARD OFFLAP OF THE SALT LAYERS AT THE TOP OF THE HUTCHINSON. CM_3 DIVIDES THE SALT INTO AN UPPER AND LOWER SECTION. THIS WILL BE IMPORTANT TO LATER DISCUSSIONS.

THE WEST TO EAST CROSS SECTION D_1-D_4 AGAIN USING GAMMA RAY-NEUTRON LOGS EXTENDS ACROSS THE SALT BASIN OVER TO THE EAST SIDE. THE DATUM IS AGAIN THE WELLINGTON MARKER. ANHYDRITES ARE MORE PREVALENT IN THE WEST AND EVEN MORE SO SOUTHWEST OF THE LINE OF SECTION. OVERALL THE SALT IS CLEANER IN THE EAST AND NORTHEAST WITH SHALE MORE ABUNDANT THAN ANHYDRITE.

THE EASTERN EDGE OF THE SALT IN CENTRAL KANSAS IS A ~~DISSOLUTION~~ FRONT, EXPRESSED BY A RAPID DECREASE IN THICKNESS FROM THE TOP DOWNWARD OCCURRING AT SHALLOW DEPTHS. A LOST CIRCULATION ZONE, NUMEROUS SUBSIDENCE FEATURES, AND BRINE SEEPS OCCUR IN ASSOCIATION WITH THIS SOLUTION EDGE AS DESCRIBED IN PUBLICATIONS BY LANE AND MILLER, BOB WALTERS, AND MOST RECENTLY, TONY GOGEL.

THIS IS THE TOTAL NET SALT ISOPACH OF THE HUTCHINSON SALT INTERVAL. THE SALT AS PREVIOUSLY MENTIONED COVERS NEARLY 37,000 MI^2 RANGING FROM 0 TO NEARLY 400 FEET IN THICKNESS. THE SALT IS THICKEST ALONG A SW-NE TREND FROM KIOWA COUNTY TO RICE COUNTY. THE SALT AVERAGES APPROXIMATELY 250 FEET (76 M) IN THICKNESS. THE SALT GRADES RAPIDLY TO ANHYDRITE AND SHALE ON THE SW AND WEST AND GRADES TO SHALE ON THE NORTH AND SOUTHEAST. THE SOLUTION FRONT IN THE EAST, IDENTIFIED AS CLOSELY SPACED CONTOURS, EXTENDS NORTH TO SOUTH FROM THE CITY OF SALINA TO JUST SW OF WICHITA ALONG A 84 MI (135 KM) LENGTH. SOUTH OF THIS FRONT THE CONTOURS OPEN AND REPRESENT NONE OR JUST VERY LIMITED SOLUTION.

AN ISOPACH ~~MAP~~ OF THE LOWER NET SALT IS ON THE LEFT SCREEN. IT INCLUDES ONLY THE SALT BELOW THE CM_3 MARKER. IT PRESENTS A SIMPLER PATTERN THAN THE TOTAL NET SALT MAP. A THICKENED LOBE OR DEPOCENTER OF SALT ILLUSTRATED ON THIS VARIABLE DENSITY PRESENTATION OCCURS ALONG A NW-SE TREND FROM BARTON TO SEDGWICK COUNTIES. THE DEPOCENTER IS IN THE NE SECTOR OF THE OVERALL SALT MASS. MAXIMUM THICKNESS IS JUST OVER 200 FEET IMMEDIATELY WEST OF HUTCHINSON. IT IS IN THE LOWER PORTION OF THIS INTERVAL THAT SALT IS MECHANICALLY MINED UNDERGROUND.

THE UPPER SALT ISOPACH ~~NOW SHOWN~~ ON THE RIGHT SCREEN SHOWS A REGRESSIVE OR SW OFFLAP WITH RESPECT TO THE LOWER SALT ISOPACH WITH ITS DEPOCENTER OF SIMILAR THICKNESS AS THE LOWER SALT, BUT DISPLACED TO THE SW. AS YOU MAY RECALL THIS UPPER SALT INTERVAL ACTUALLY REPRESENTS A SERIES OF SALT BEDS SEPARATED BY NUMEROUS ANHYDRITES AND SHALES. THE DEPOCENTER ALSO TRENDS MORE WEST TO EAST, CENTERED IN KIOWA COUNTY.

THE MAP DEPICTING THE RATIO OF NET SALT TO THE ~~INTERVAL~~ THICKNESS OF THE TOTAL SALT BEARING INTERVAL OR SALT PERCENTAGE MAP, REPRESENTS A VERY ASSYMETRIC BUT REGULAR PATTERN. THE PERCENTAGE OF SALT IS HIGHLIGHTED HERE BY A VARIABLE DENSITY PRESENTATION BETWEEN CONTOUR INTERVALS OF 20% INCREMENTS. THE % OF HALITE INCREASES TOWARD THE NE QUADRANT OF THE HUTCHINSON SALT UNIT REFLECTING THE NET SALT ISOPACH MAPS, BUT IN CONTRAST TO THE INTERVAL ISOPACH SHOWN EARLIER. HALITE PERCENTAGE IS GREATER THAN 90 IN AREAS ~~SLIGHTLY~~ WEST OF HUTCHINSON.

NOTE THE SALT DISSOLUTION FRONT ON THE EAST COMPARED TO DEPOSITIONAL PINCHOUT OF THE SALT IN THE SE AND AROUND THE NORTH AND WEST EDGES. THE SE AND NORTH FLANKS ARE SIMILAR TO EACH OTHER WITH A RATHER RAPID TRANSITION OF HALITE TO SHALE WHEREAS THE WEST EDGE IS CHARACTERIZED BY MORE LENGTHY INTERFINGERING OF HALITE WITH ANHYDRITE AND SHALE UNITS.

THE BROADLY SPACED CONTOURS OF THE WEST AND CLOSELY SPACED CONTOURS OF THE NORTH EDGES CONVERGE SHARPLY IN AN AREA IN NW LANE COUNTY IN NW KANSAS NEAR THE ARROW SHOWN ON THE MAP. FROM THIS PIVITAL POSITION NOTE HOW THE GENERALLY NORTH-SOUTH ORIENTED

CONTOURS DIRECTLY SOUTH OF THIS POINT FAN OUT AND BECOME MORE WIDELY SPACED NW-SE TRENDING. THIS BROAD RATHER UNIFORM CONFIGURATION STRONGLY SUGGESTS TO ME A CONTINUUM OF RELATED AND SIGNIFICANT PROCESSES WHICH AFFECTED THE SEQUENCE OF SALT BEDS AS THEY WERE DEPOSITED ACROSS THIS BASIN.

THE CONTOUR MAP DEPICTING DEPTH TO THE TOP OF THE HUTCHINSON SALT IS A PRODUCT OF BOTH THE TOPOGRAPHY AS ESTIMATED BY THE ELEVATIONS OF THE DATA POINTS AS WELL AS THE STRUCTURAL CONFIGURATION OF THE TOP OF SALT. THE TOP OF SALT COMES TO WITHIN 130 FT. OF THE SURFACE IN SOME PARTS OF THE EASTERN EDGE WHILE THE SALT IS BURIED TO DEPTHS IN EXCESS OF 2500 FEET (762 M) IN NW KANSAS. FROM NORTH TO SOUTH MAJOR RIVER VALLEYS SUCH AS THE SALINE AND SMOKEY HILL RIVERS FORM NOTABLE EAST TO WEST TRENDS ON THIS MAP.

A STRUCTURAL CONTOUR MAP ON TOP OF THE NOLANS LIMESTONE OF THE CHASE GROUP, REVEALS A BROAD E-NE TRENDING STRUCTURAL SADDLE SEPARATING SOUTHWARD AND NORTHWARD PLUNGING BASINS. THE SOUTHERLY ONE CONFORMS TO THE HUTCHINSON INTERVAL ISOPACH WHICH IS SHOWN AGAIN ON THE RIGHT SLIDE. THE SADDLE PROBABLY REPRESENTS LATER UPLIFT AFTER SALT DEPOSITION. NOTE THAT THE EAST FLANK OF THE SOUTHERLY BASIN DIPS MORE STEEPLY THAN THE WEST FLANK. SIMILARLY, THE NORTHWEST FLANKS OF THE NE TRENDING ANTICLINES ON THE EAST SIDE OF THE BASIN ARE DIPPING MORE STEEPLY THAN THEIR SE FLANKS. ALL OF THIS SUGGEST POST-DEPOSITIONAL WESTWARD TILTING. OTHER WORKERS HAVE DOCUMENTED SUCH AN EPISODE OF TILTING AS HAVING OCCURRED DURING THE CRETACEOUS. PRIOR TO THE CENTRAL FLEXURE AND

TILTING, THE SALT BASIN WAS LIKELY A COMBINED STRUCTURAL-DEPOSITIONAL BASIN CONFORMING IN BOTH SHAPE AND RELIEF TO THE HUTCHINSON INTERVAL ISOPACH WITH THE SALT DEPOSITED PASSIVELY WITHIN THIS SHALLOW CRUSTAL DEPRESSION.

THE STRUCTURAL CONTOUR MAP ON THE TOP OF THE SALT REFLECTS BOTH THE STRUCTURAL CONFIGURATION ON THE SALT COMBINED WITH THE LOSS OF UPPER SALT LAYERS NORTHWARD IN THE BASIN. NEVERTHELESS, THE PATTERN IS SIMILAR TO THE CHASE STRUCTURE WHICH IS STILL ON THE LEFT SCREEN. THE PRESENT EASTERN SOLUTION EDGE LIES ON THE WEST FLANK OF A CLOSED DEPRESSION FORMED IN RESPONSE TO PREVIOUS SALT SOLUTION. IT IS THE PLEISTOCENE EQUUS BED AQUIFER WHICH FILLS THIS SOLUTION AREA IN RENO CO. NOTE THAT SOUTH OF THIS AREA THE CONTOUR INTERVAL APPEARS VERY REGULAR AGAIN SUGGESTING NO MAJOR SOLUTION ACTIVITY.

DISCUSSION AND INTERPRETATION

THE FOUNDATION FOR THIS SUBSURFACE STUDY IS INTEGRATING CORE DESCRIPTIONS WITH LOG MEASUREMENTS AND THEN USING LOG SIGNATURES FOR MAPPING. A PLOT OF GAMMA RAY VERSUS NEUTRON RESPONSE FOR A SINGLE LOG SHOWN ON THE LEFT SCREEN ILLUSTRATES THE DISTINCTION THAT IS POSSIBLE BETWEEN MAJOR FACIES TYPES IN THE WELLINGTON INTERVAL.

USING LOG SIGNATURES TO DIFFERENTIATE THE FACIES, I MADE TWO DETAILED STRATIGRAPHIC CROSS SECTIONS THOSE DATUM IS THE BASE OF THE HUTCHINSON SALT. ORIGINAL WELL SPACING WAS BETWEEN FIVE AND TWENTY MILES.

THE NORTHWEST TO SOUTHEAST SECTION ON THE LEFT SCREEN EXTENDS BEYOND THE SALT EDGE ON THE NORTHWEST, SOUTHEASTWARD TO THE CENTER OF

THE SALT BASIN IN KANSAS. THE SALT LAYER IN PINKISH RED IS ACTUALLY COMPRISED OF MANY UNITS SEPARATED BY SHALES IN BLUE AND SEVERAL EXTENSIVE ANHYDRITE MARKERS, ONE OF WHICH IS OUTLINED. THE YOUNGER SALT LAYERS ARE OFFLAPPING TO THE SOUTH.

THE OTHER CROSS SECTION SHOWN ON THE RIGHT EXTENDS 250 MILES ACROSS THE SALT UNIT FROM SW TO NE. THE SALT IS MORE MASSIVE ON THE NORTHEASTERN END OF THE SECTION. THE INDIVIDUAL SALT UNITS GENERALLY THIN, INTERFINGER WITH, AND PROGRADE OVER ANHYDRITE TO THE SOUTHWEST. THIS WAS ALSO APPARENT ON THE PERCENTAGE HALITE MAP SHOWN EARLIER. NOTICE HOW THE HALITE IN THE LOWER SALT INTERVAL PROGRADES OVER ANHYDRITE TO THE SOUTHWEST.

STATISTICAL ANALYSIS OF THE DETAILED CORE DESCRIPTION OF ~~A CORE OF~~ THE SALT TAKEN NEAR HUTCHINSON, KANSAS CONFIRMS THAT A SIGNIFICANT VERTICAL EVAPORITE CYCLE IS DEVELOPED THROUGH THE CORE. THE CYCLE BEGINS WITH EITHER CARBONATE OR ANHYDRITE AND, PROBABLY BECAUSE THE BRINE BECAME MORE CONCENTRATED HALITE PRECIPITATION FOLLOWED. RECRYSTALLIZED, ARGILACEOUS HALITE NORMALLY SUCCEEDS A PRIMARY HALITE WHICH IS IDENTIFIED AS WELL BEDDED AND FULL OF FINE BRINE INCLUSIONS. CYCLES ARE EACH ONLY SEVERAL METERS IN THICKNESS AND THE ENTIRE HUTCHINSON SALT IS COMPRISED OF SEVERAL DOZEN CYCLES. ONLY OCCASIONALLY DO ANHYDRITES EXCEED SEVERAL FEET IN THICKNESS AND ARE EASILY DISTINGUISHABLE ON WELL LOGS. THESE THICK ANHYDRITES PROBABLY REPRESENT AN EVENT THAT IS NOT TYPICAL IN A CYCLE. FURTHERMORE, IT IS THOUGHT THAT THE THICK ANHYDRITES REFLECT PERIODIC FRESHENING OF AN EXTENSIVE BRINE.

ON THE LEFT SLIDE I HAVE ATTEMPTED TO DEPICT AN EVAPORITIC CYCLE CHARACTERISTIC OF THE HUTCHINSON SALT AS IT DEVELOPS: AS A SEQUENCE OF PLANE VIEW MAPS AND AS GREATLY EXAGGERATED CROSS SECTIONS ACROSS A SALT BASIN MODELED AFTER THAT OF THE HUTCHINSON IN KANSAS. INTERPRETATION IS BASED ON CORE DESCRIPTION, DETAILED CROSS SECTIONS, AND THE MAPS OF THE SALT. I AGAIN SUGGEST HERE THAT THE SALT WAS DEPOSITED IN AN EXTENSIVE BRINE BODY.

DURING STAGE ONE PRIMARY HALITE IS PRECIPITATED IN THE NORTHEAST PORTION OF THE BASIN AT THE SAME TIME THAT ANHYDRITE IS ACCUMULATING TO THE SOUTHWEST. GREEN SHALE ACCUMULATED ALONG THE NORTH AND EAST MARGINS OF THE BASIN AND INTERFINGERED WITH THE SALT. THE MAPS AND CROSS SECTIONS SHOWN EARLIER DEMONSTRATE THIS.

During stage two

WITH A FALL IN BRINE LEVEL THE HALITE PRECIPATION SHIFTS TO THE SOUTHWEST WITH RECRYSTALLIZED HALITE, SHOWING EFFECTS OF SECONDARY ALTERATION, DEVELOPING NOW IN THE NORTHEAST WHERE THE BRINE IS SHALLOWER AND WHERE WATER CONDITIONS MAY BE MORE VARIABLE.

DURING THE THIRD STAGE THE LEVEL OF THE BRINE BODY RISES AS TRANSGRESSION OCCURS FROM THE SOUTHWEST BRINGING IN LESS SALINE BRINE PRODUCING A THIN BLANKET OF ANHYDRITE. RECONCENTRATION OF THE BRINE THROUGH EVAPORATION EVENTUALLY RESULTS IN MORE HALITE PRECIPITATION FORMING ANOTHER SALT LAYER. THE END RESULT IS MORE HALITE IN THE NORTHEAST AND MORE ANHYDRITE IN THE SOUTHWEST.

PRESENT DAY KNOWLEDGE ABOUT MANY SMALL SCALE AND MICROSCOPIC STRUCTURES IN HALITE DO NOT CONCLUSIVELY RESOLVE WHETHER OR NOT A HALITE BED WAS DEPOSITED IN A SERIES OF SHALLOW TO EMERGENT BRINE PANS OR IN A MORE EXTENSIVE INLAND SEA. JIM BERG, AN M. S. CANDIDATE AT KU, IS NOW DOING DETAILED THIN SECTION MICROSCOPY AND BROMIDE ANALYSES ON A MICRO SCALE OF THE HUTCHINSON IN AN ATTEMPT TO ANSWER

THIS QUESTION. I PREFER THE LATTER ORIGIN FOR THE HUTCHINSON SALT BASED ON (1) THE OVERALL FACIES PATTERN AND (2) COMPLEMENTED BY THE GENERAL BROMIDE PROFILE ALSO DONE IN THIS STUDY WHICH I HAVE NOT YET DISCUSSED.

BROMIDE ANALYSES OF THE HALITE SUGGESTS A MARINE SOURCE FOR THE BRINES WHICH DEPOSITED THE HALITE RATHER THAN PRECIPITATION FROM GROUNDWATER WHICH IS THOUGHT TO BE THE CONDITION FOR FORMATION OF THE YOUNGER FLOWER POT SALT PRESENT IN WESTERN KANSAS.

FURTHER SUPPORT FOR AN INLAND SEA MAY BE OBTAINED FROM A REGIONAL EXAMINATION OF THE GEOLOGIC SETTING OF THE HUTCHINSON SALT. THIS WILL ALSO LEAD TO AN ANSWER FOR THE QUESTION POSED EARLIER AS TO WHY EVAPORITES AND REDBEDS SUCCEEDED NORMAL MARINE SEDIMENTS DURING THE PERMIAN IN THE MIDCONTINENT.

ON THE LEFT SCREEN IS A GLOBAL MAP SHOWING THE DISTRIBUTION OF THE CONTINENTS DURING THE LOWER PERMIAN FROM BAMBECK AND OTHERS. THE PRESENT OUTLINES OF THE CONTINENTS ARE SHOWN. BROWN COLORED REGIONS WERE LANDMASSES DURING THE LATE PERMIAN. THE WESTERN MIDCONTINENT WAS PART OF A SUPERCONTINENT, PANGEA, FORMED THROUGH THE COLLISION OF GONDWANALAND TO THE SOUTH AND LAURUSSIA, WHICH THE MIDCONTINENT REGION WAS A PART. THE COLLISION BEGAN IN THE OUACHITAS IN LATE MISSISSIPPIAN AND MOVED SOUTHWESTWARD INTO THE MARATHONS BY THE EARLY PERMIAN. BY THIS TIME THE LAND MASSES WERE TOGETHER WHICH BROUGHT AN END TO A LONG PERIOD OF DRIFT OF MANY INDIVIDUAL CONTINENTS DURING MUCH OF THE PALEOZOIC.

ON THE RIGHT SCREEN ARE A GLOBAL SEA LEVEL CURVE FROM VAIL, ETAL DERIVED FROM THE BUDDING DISCIPLINE OF SEISMIC STRATIGRAPHY AND A NORTH AMERICAN FREEBOARD CURVE FROM WISE SHOWING THE PERCENTAGE OF

THE HUTCHINSON SALT DEPOSITION.

IN WOLFCAMP TIME CARBONATES ACCUMULATED ACROSS MUCH OF THE MIDCONTINENT SHELF DEPOSITED IN A SEA WHICH WAS CONNECTED TO THE DEEP WATER "PERMIAN OCEAN" COVERING THE MIDLAND AND DELAWARE BASINS OF WEST TEXAS AND NEW MEXICO. EVAPORITES OF WOLFCAMP AGE ARE RESTRICTED TO TWO AREAS OF THE MIDCONTINENT INCLUDING THE ALLIANCE BASIN OF WESTERN NEBRASKA AND NORTHEASTERN COLORADO SITUATED ON THE NORTHWEST FLANK OF THE ACTIVE LOS ANIMAS ARCH.

THIS PARTICULAR AREA HAD ONLY A SHALLOW WATER CONNECTION TO THE WESTERN OCEAN OVER THE WYOMING SHELF. AT THIS TIME OF COURSE THE RESERVOIR ROCKS OF THE HUGOTON AND PANOMA GAS AREAS WERE BEING DEPOSITED AND OVER AN AREA WHAT IS NOW AN EXTENSIVE SHALLOW GAS TREND IN CENTRAL KANSAS. WHAT REMAINED OF THE OUACHITA AND THE MARATHON UPLIFTS RIMMED THE EAST AND SOUTHEAST.

THE DALHART BASIN SEPARATING SHELF CARBONATE OF THE MIDLAND BASIN FROM KANSAS WAS A DEEPER WATER BASIN RIMMED BY A CARBONATE SHELF AS RECENT WORK BY SHIRLEY DUTTON AND ROBERT HANFORD OF THE TEXAS BUREAU OF ECONOMIC GEOLOGY DEMONSTRATES. THIS ALLOWED ACTIVE WATER CIRCULATION OVER THE KANSAS SHELF. ELEVATED SALINITIES ON THE KANSAS SHELF DURING THIS TIME WERE TEMPORARY PROBABLY DUE TO MINOR CHANGES IN SEA LEVEL.

THE LOWER LEONARD STAGE DURING WHICH THE HUTCHINSON SALT WAS DEPOSITED HAS A COMPLETELY DIFFERENT FACIES PICTURE THAN EARLIER TIMES. EVAPORITES PREDOMINATE OVER THE MAP AREA FROM THE NORTHERN MIDLAND BASIN INTO KANSAS.

TWO FACTORS MAY HAVE AFFECTED THE DEVELOPMENT OF THIS NEW EVAPORITIVE REALM.

FIRST--MORE ARID CLIMATE AS RECOGNIZED IN THE FLORA AND SEDIMENT COLOR OF THE ROCK RECORD. SECONDLY--THE FILLING OF THE DALHART BASIN WITH SEDIMENT (I.E., WHERE SEDIMENTATION RATE EXCEEDED THE RATE OF SUBSIDENCE). THIRDLY--THIS BASIN FILLING WAS CONCURRENT WITH A BUILDUP AND PROGRADATION OF THE CARBONATE SHELF ALONG THE MARGIN OF THE MIDLAND BASIN REFLECTING A CHANGE IN THE RATE OF SHELF SUBSIDENCE. THE COMBINED RESULT MUST HAVE BEEN THE RESTRICTED ACCESS OF WATER FLOW TO THE KANSAS SHELF AREA. THE RESULTANT BRINES COULD THEN CONCENTRATE AS THEY FLOWED NORTHWARD IF RUNOFF WAS SMALL AND EVAPORATION RELATIVELY HIGH. THE SEDIMENTS FOUND IN THIS AREA REFLEC THE ACTIVE PROCESSES--EVAPORITES, FIRST CARBONATE AND SULFATE ACCUMULATED NEAR THE MIDLAND BASIN AND FINALLY HALITE PRECIPITATED ON THE KANSAS SHELF, AN AREA WHICH WAS MOST ISOLATED FROM THE OPEN OCEAN.

TWO SOUTHWEST TO NORTHEAST CROSS SECTIONS FROM WEST TEXAS TO CENTRAL KANSAS DEMONSTRATE THIS FACIES CHANGE IN HUTCHINSON AGE EQUIVALENT ROCK STRATA. THE WICHITA GROUP CARBONATES OF THE SHELF MARGIN BUILT TO SEA LEVEL; BUILDING TO COMPENSATE FOR ANY CHANGES IN SEA LEVEL AND ESSENTIALLY ACTING AS BROAD SILL WHICH RESTRICTED THE EXCHANGE OF WATER BETWEEN THE SHELF AND BASIN. THE SECOND CROSS SECTION ON THE RIGHT INCLUDING DATA FROM A NUMBER OF SOURCES SHOWS THE WICHITA GROUP CARBONATES BECOMING SULFATE RICH TO THE NORTHEAST AND EVENTUALLY TO ENTIRELY A SULFATE COMPOSITION. WITH FURTHER RESTRICTION AND ELEVATION OF SALINITY THE SULFATE PRECIPITATION CHANGED TO THAT OF HALITE WHICH BECAME THE HUTCHINSON IN KANSAS.

ON THE LEFT SCREEN A QUANTITATIVE EVAPORITE MODEL PUBLISHED IN 1960 BY , WHICH CLOSELY FITS SCRUTON'S GRAPHIC MODEL SHOWN BELOW IT. PREDICTS THE OCCURRENCE OF HALITE IN THIS TYPE OF SETTING WHERE A SHALLOW EVAPORITE BASIN FILLED WITH BRINE, IS SEPARATED FROM THE OPEN SEA BY A SILL. IN THIS CASE THE SILL IS A SHALLOW TO EXPOSED CARBONATE SHELF IN WEST TEXAS. A BROAD LATERAL FACIES PATTERN GOING FROM CARBONATE TO SULFATE TO HALITE IS PREDICTED. THIS FITS VERY WELL WITH THE GEOLOGIC SETTING AND STRATIGRAPHY OF THE HUTCHINSON SALT AND EQUIVALENT STRATA.

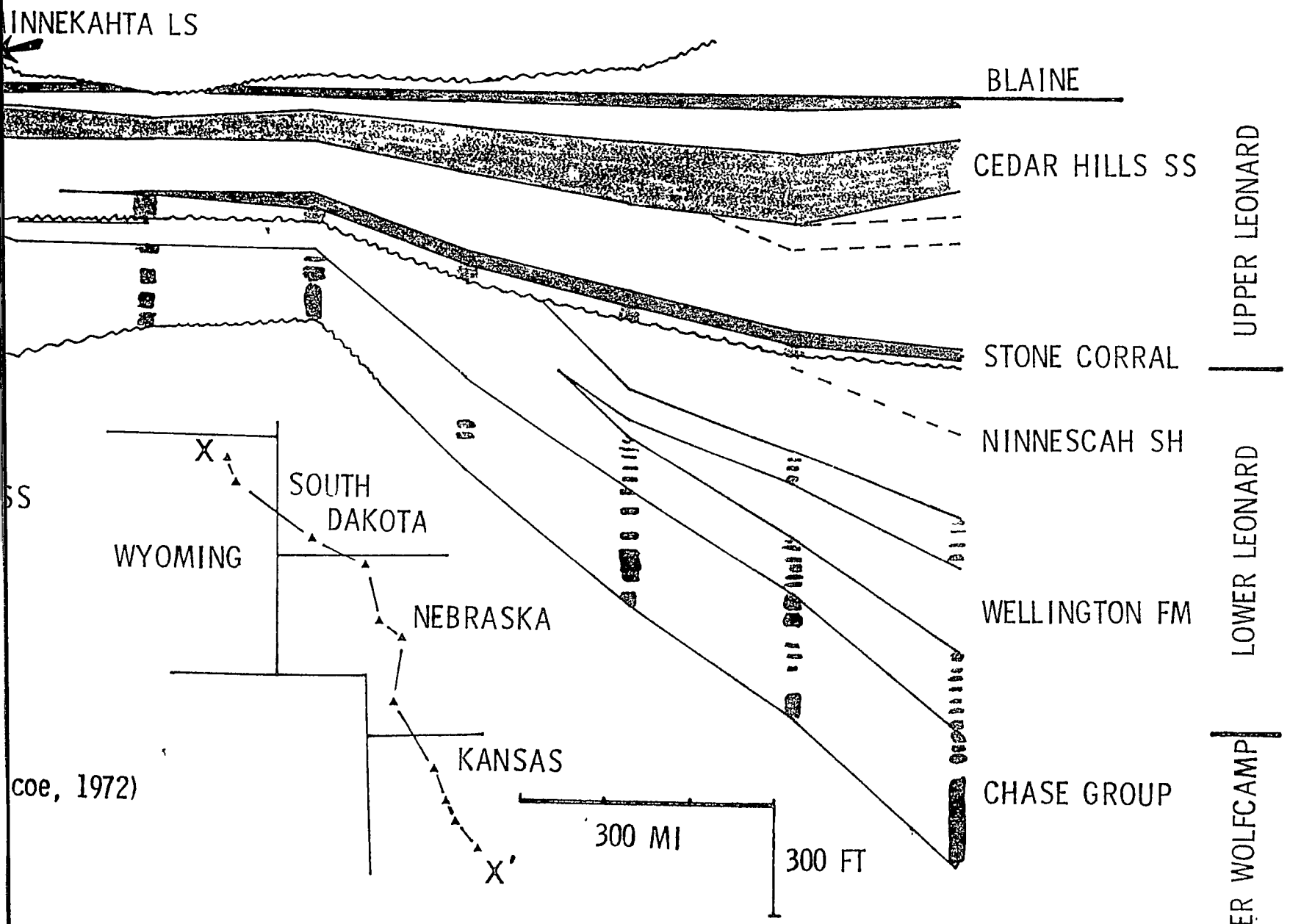
HOLD R28 Summary

THE DETAILED STRATIGRAPHY OF THE HUTCHINSON SALT SUPPORT AN EXTENSIVE BRINE BODY WITH A SOUTHWEST CONNECTION TO THE SEA. HALITE ACCUMULATED UNDER GENERAL REGRESSIVE SEDIMENTATION INFERRED FROM A FACIES OFFLAP TO THE SOUTHWEST AS THE BASIN FILLED AND THE SEA WITHDREW. FINALLY, REDBEDS OF THE NINNESCAH SHALE PROGRADED OVER THE BASIN. THE NINNESCAH REPRESENTS A NEARSHORE TO SUBAERIAL CLASTIC ACCUMULATION. KANSAS WAS NOT COVERED AGAIN BY THE SEA UNTIL STONE CORRAL TIME. THIS WAS THE BEGINNING OF THE UPPER LEONARDIAN ON THE MIDCONTINENT AND ANOTHER EPISODE OF EVAPORITE DEPOSITION.

LEFT SCREEN	RIGHT SCREEN
L1. BASS MAP	OFF
L2. HOLD	R1. NW-SE CROSS SECTION
L3. COMBINED SALT MAP	HOLD
L3. INDEX MAP FOR STUDY	HOLD
HOLD	R2 SHALE WITH HALITE
HOLD	R3 CONTORTED SHALE
HOLD	R4 ANHYDRITE
HOLD	R5 ANHYDRITE AFTER GYPSUM
HOLD	R6 BEDDED PRIMARY HALITE
HOLD	R7 RECRYSAL. HLAITE
HOLD	R8 AEC WELL LOG
L4. ENTRIES FOR LOG	HOLD
L5 . Entries CALCULATED	HOLD
HOLD	R9. FLOWCHART
L6. INDEX MAP	R10. INTERVAL ISOPACH
HOLD	R11. B_1-B_4 CROSS SECTION
HOLD	R12. D_1-D_4 CROSS SECTION
HOLD	R13. NET SALT ISOPACH
L7. LOWER SALT ISOPACH	HOLD
HOLD	R14. UPPER SALT ISOPACH
HOLD	R15. SALT PERCENT
L8. DEPTH TO SALT	HOLD
L9. CHASE STRCTURE	R16. INTERVAL ISOPACH
HOLD	R17. TREND MAP
HOLD	R18. HUTCHINSON STRUCTURE
L10. CROSS PLOT (GR-N)	R19. BLANK
L11. NW-SE CROSS SECTION	HOLD
HOLD	R20. SW-NE CROSS SECTION

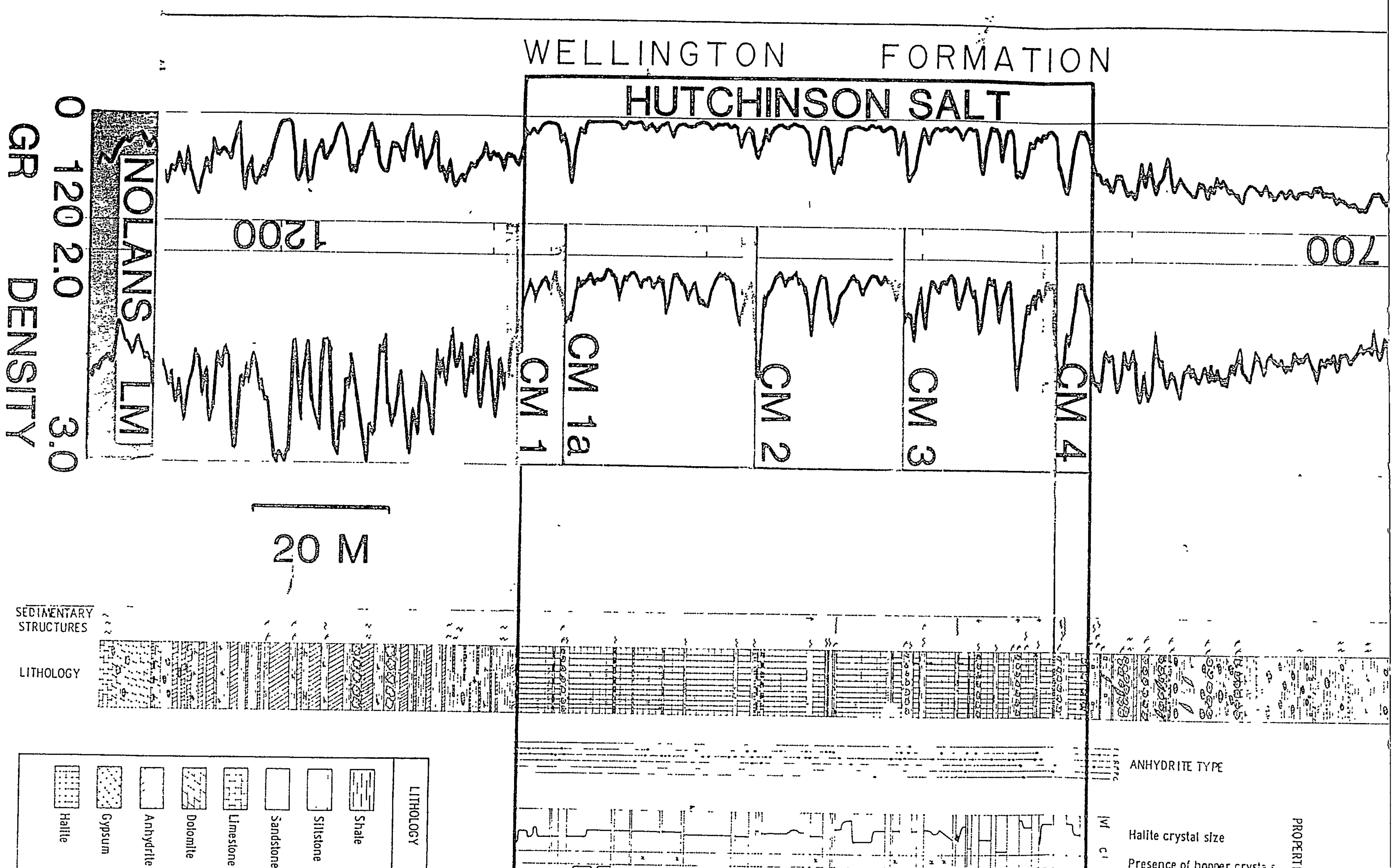
LEFT SCREEN	RIGHT SCREEN
L12. MARKOV CHAIN CYCLE	R21. CYCLE SUCCESSION
L13. CYLCE DIAGRAM	HOLD
HOLD	R22. SUMMARY TABLE
L14. EVAPORITE ABUNDANCE	HOLD
HOLD	R241 WOLFCAMP PALEOGEOG PAP
L16. LEONARD PALEOGEO PAP	HOLD
HOLD	R25. HILLS DIAGRAM
HOLD	R26. TABLE
L17. MIDLAND BASIN CROSS SEC	R27. KANSAS - TX PANHAN CROSS SECTION
L18. L_n - SCRUTON PLOT	HOLD
HOLD	R28. SUMMARY SLIDE
HOLD	R29. KGS SLIDE

RIGHT SCREEN → SOUTH



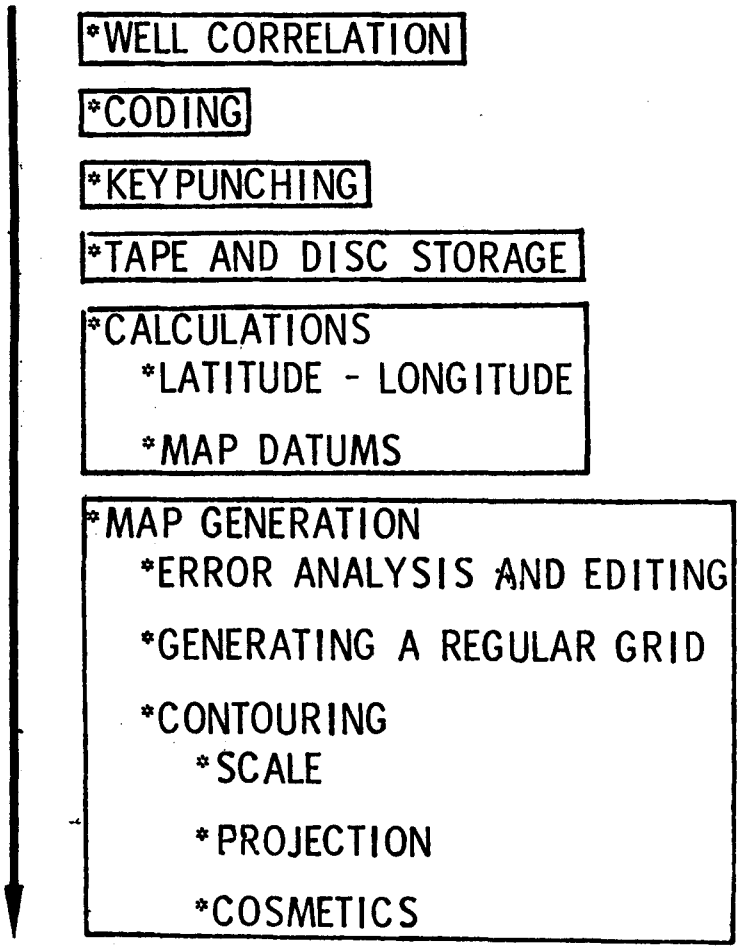
coe, 1972)

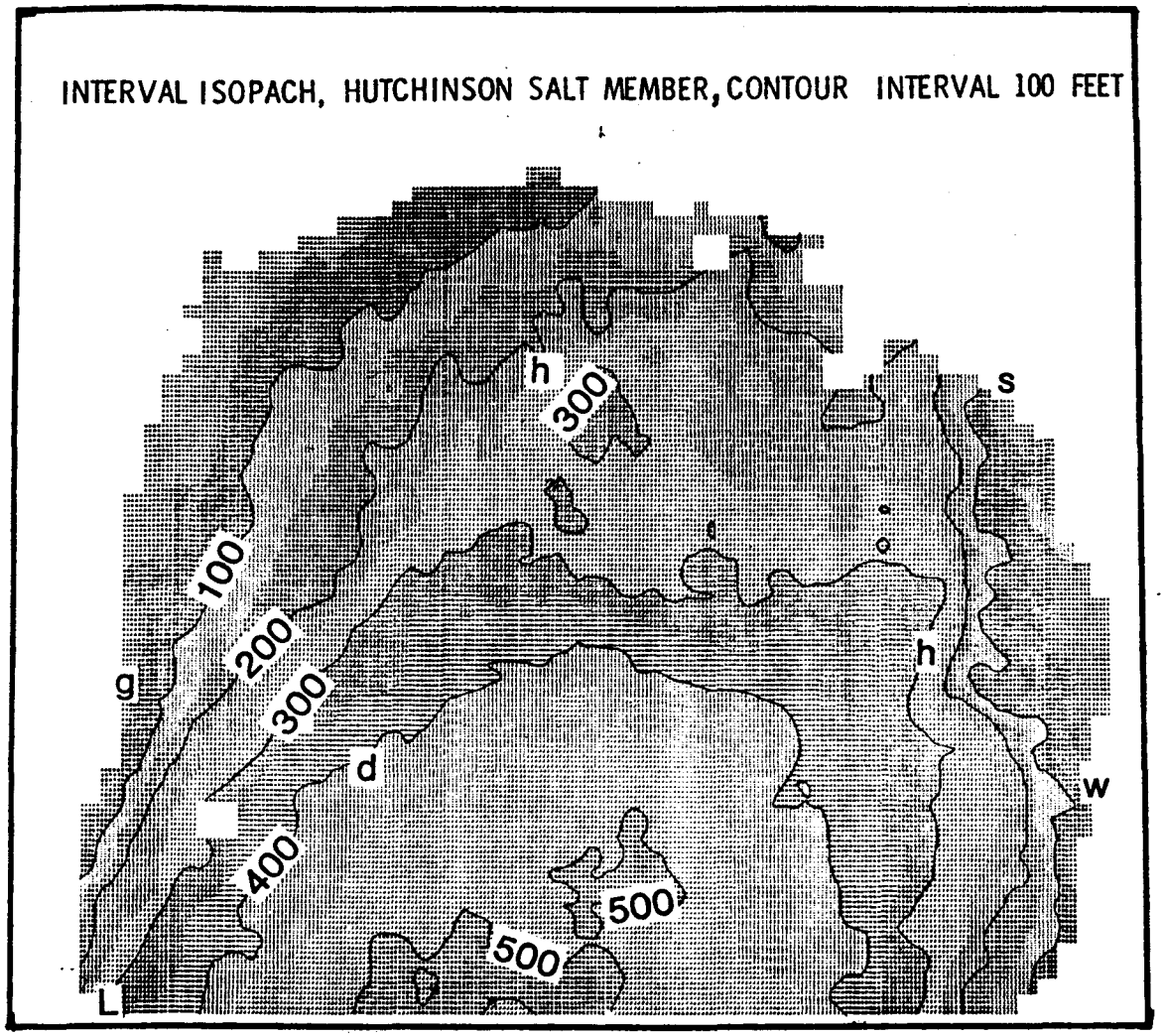
R8



WELLINGTON FORMATION
HUTCHINSON SALT
700
1200
CM 1
CM 1a
CM 2
CM 3
CM 4
NOLANS LM
0 120
GR
2.0 3.0
DENSITY
20 M
SEDIMENTARY STRUCTURES
LITHOLOGY
ANHYDRITE TYPE
Halite crystal size
vf c
LITHOLOGY
Shale
Siltstone
Sandstone
Limestone
Dolomite
Anhydrite
Gypsum
Halite

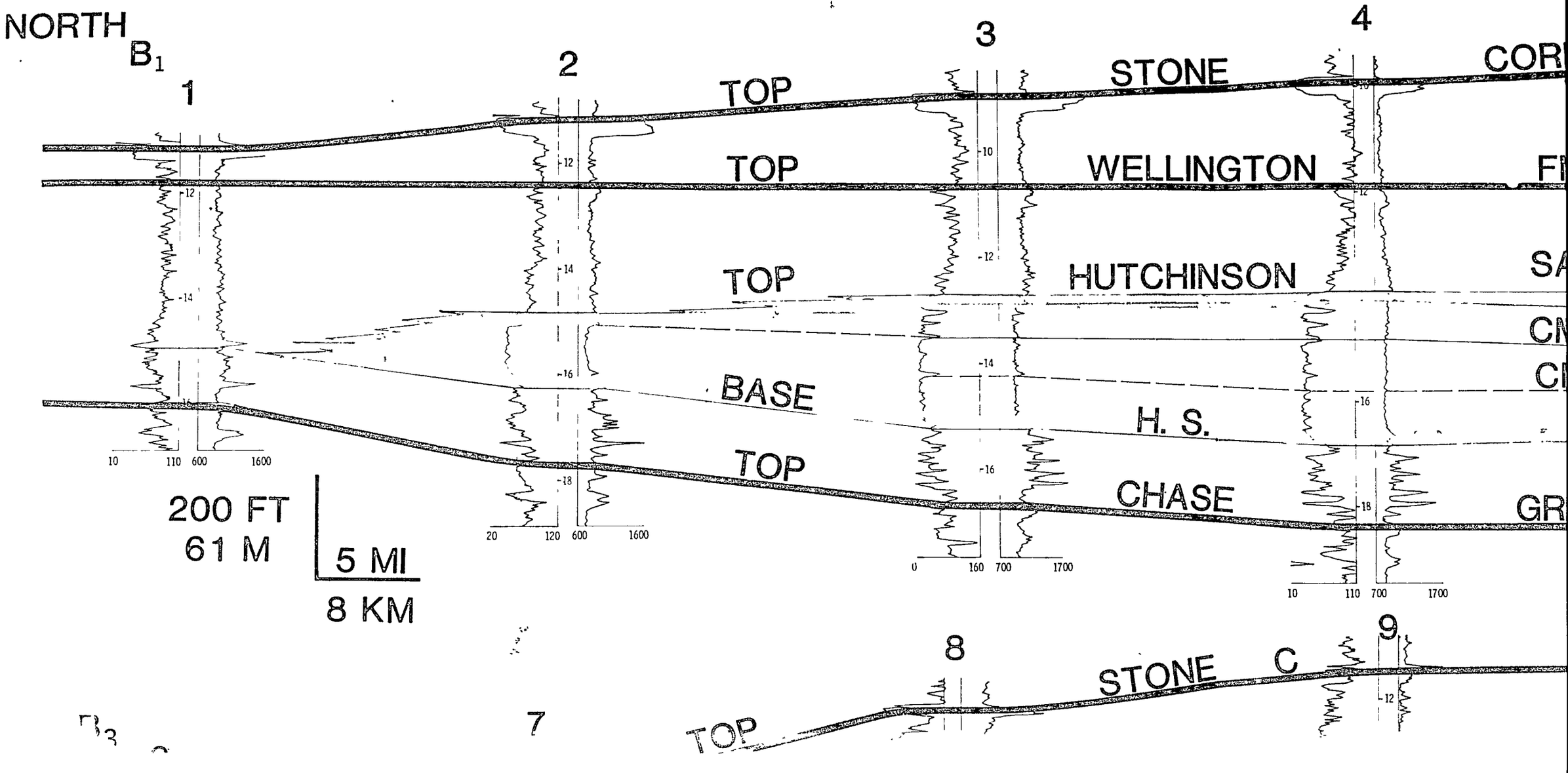
PROCEDURAL FLOWCHART



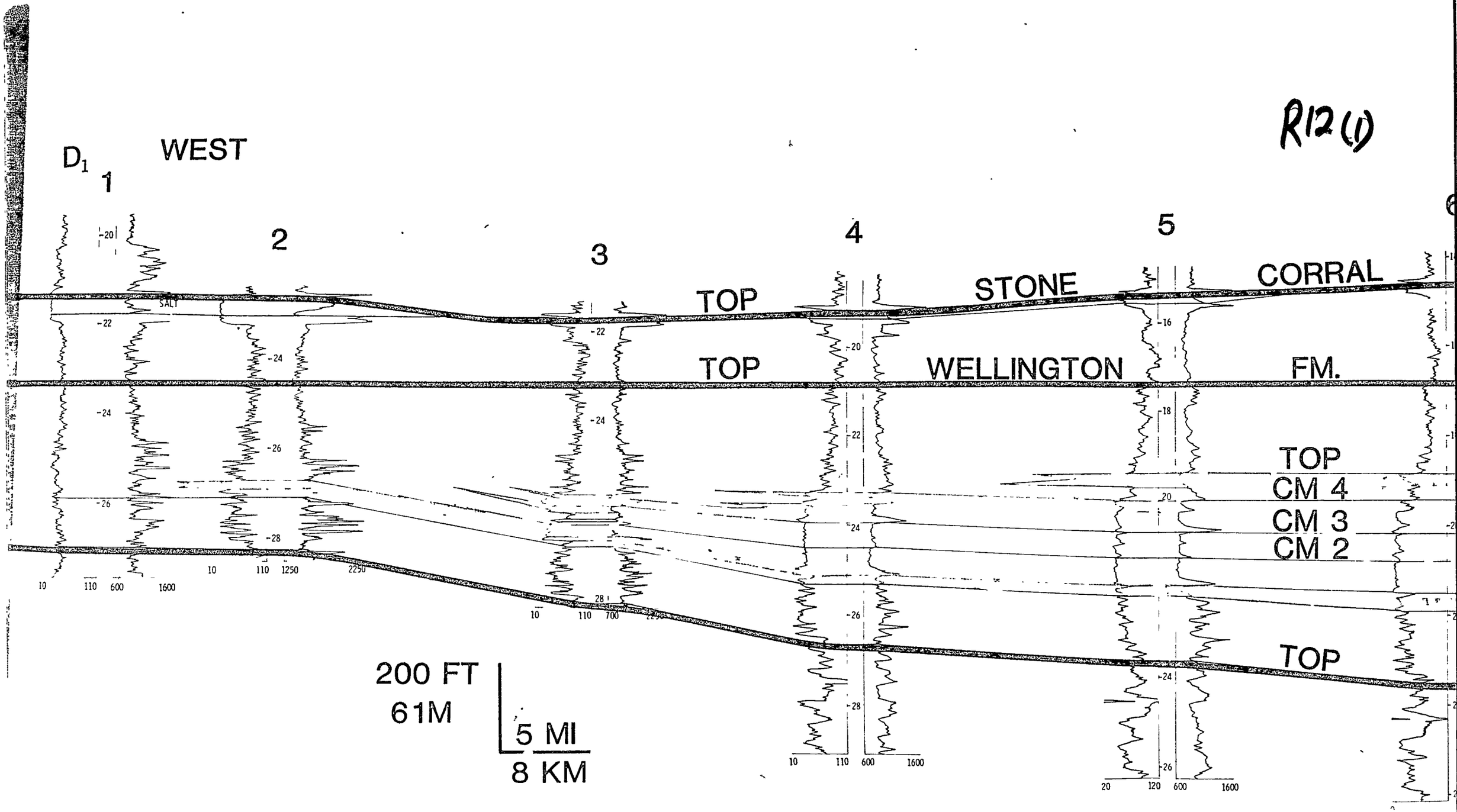

INTERVAL ISOPACH, HUTCHINSON SALT MEMBER, CONTOUR INTERVAL 100 FEET
h
300
100
200
300
400
500
500
g
d
L
h
s
w
HUTCHINSON
SALT
STUDY
NORTH
MI
0
30
0
50
KM

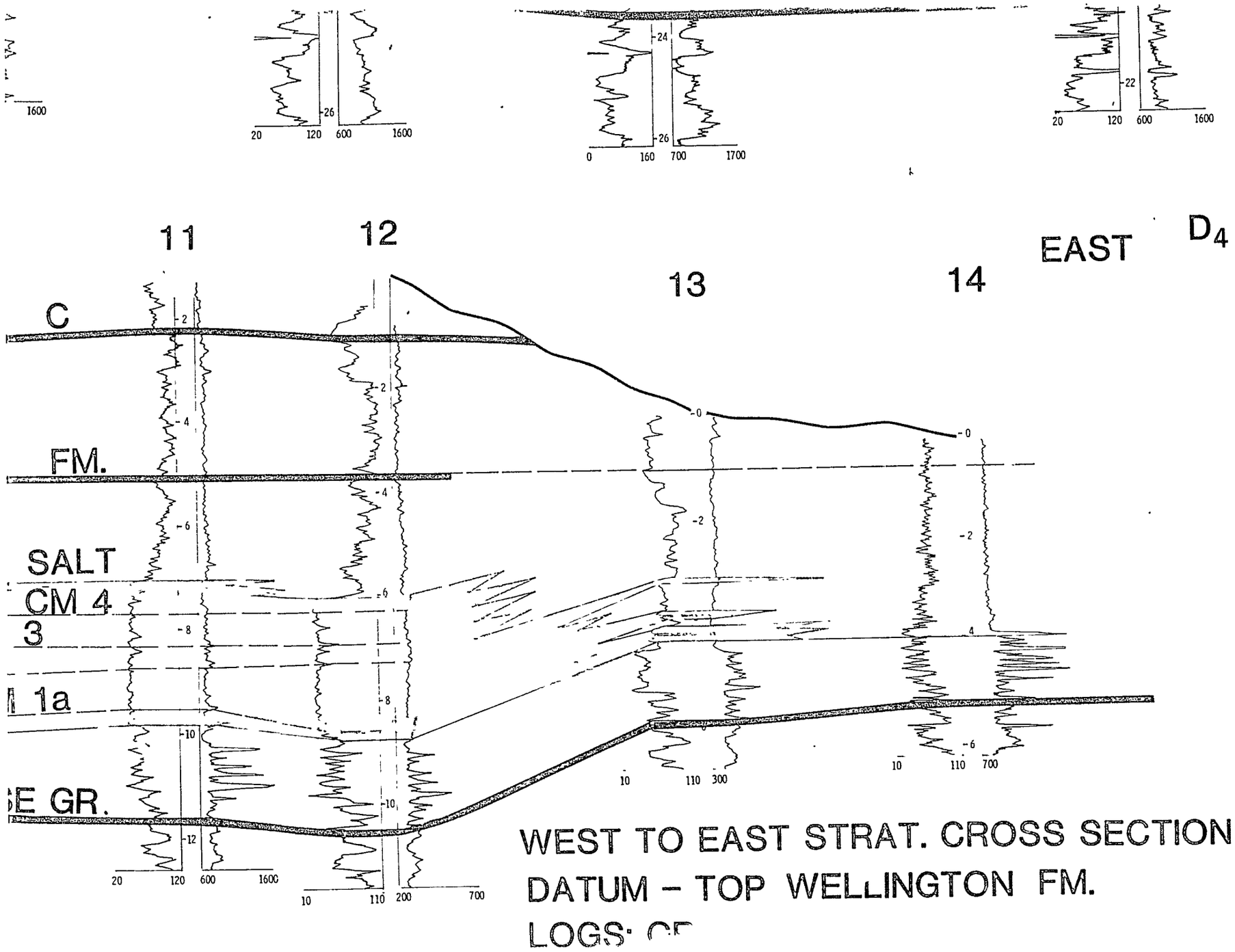
R10

R11


NORTH
B1
1
2
3
4
TOP
STONE
COR
TOP
WELLINGTON
FI
TOP
HUTCHINSON
SA
CR
CI
BASE
H. S.
TOP
CHASE
GR
200 FT
61 M
5 MI
8 KM
8
STONE
C
9
B3
7
TOP

R12 (1)


D1
WEST
1
2
3
4
5
SALT
TOP
STONE
CORRAL
TOP
WELLINGTON
FM.
TOP
CM 4
CM 3
CM 2
TOP
200 FT
61M
5 MI
8 KM

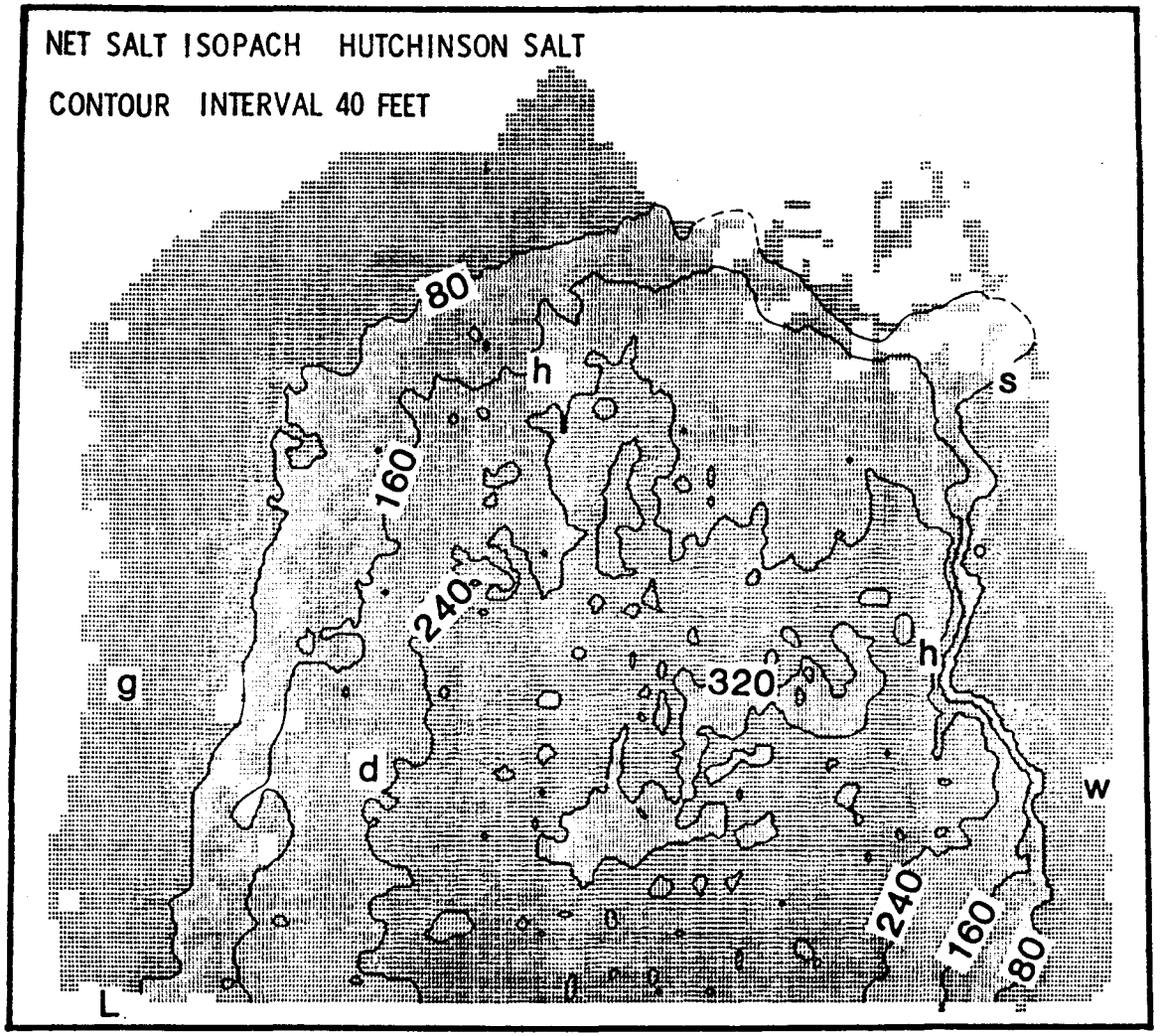


R12(2)

WEST TO EAST STRAT. CROSS SECTION

DATUM – TOP WELLINGTON FM.

LOGS: GR



HUTCHINSON
SALT
STUDY

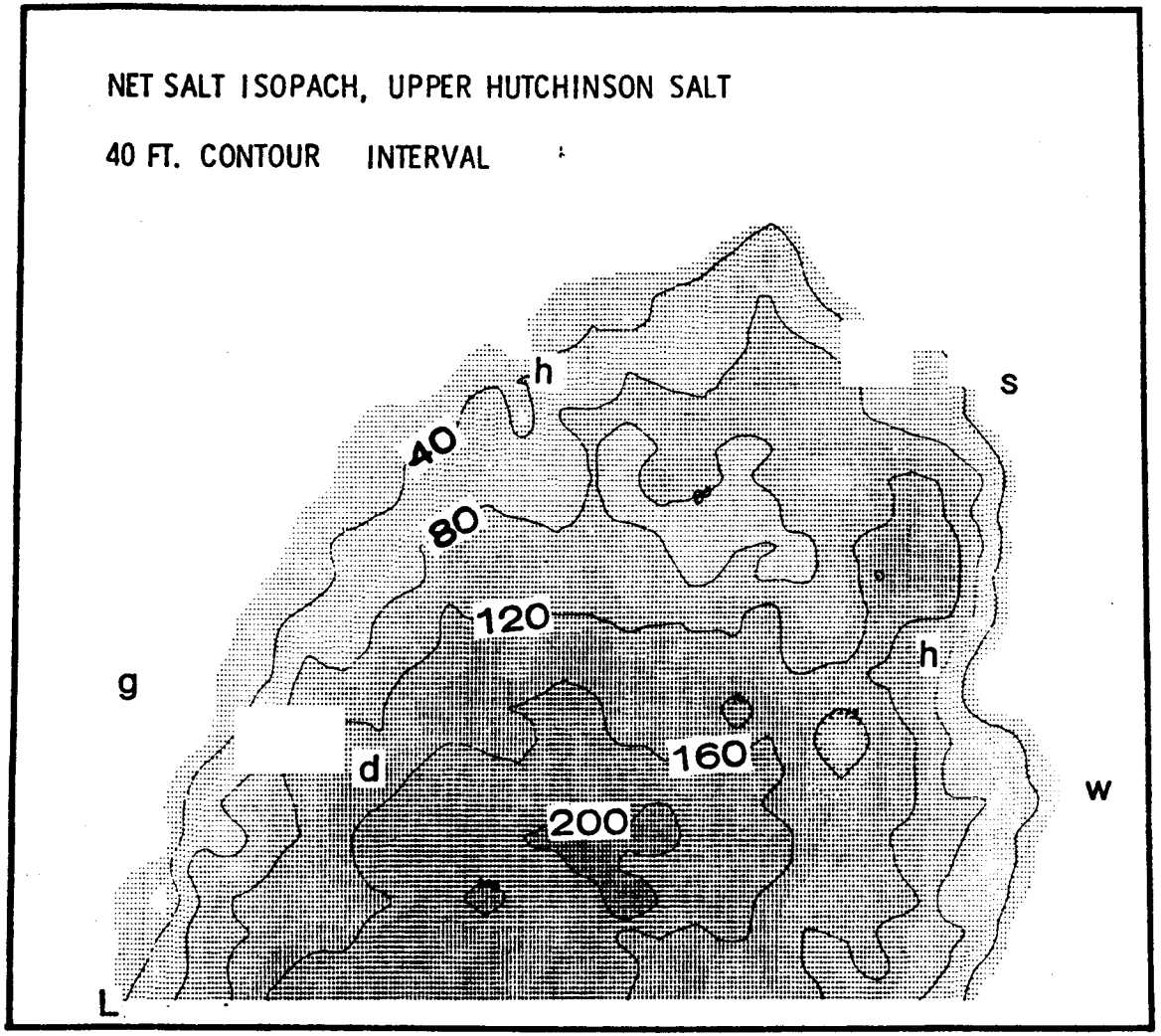
NORTH

MI
0 30
0 50
KM

R13

NET SALT ISOPACH, UPPER HUTCHINSON SALT

40 FT. CONTOUR INTERVAL

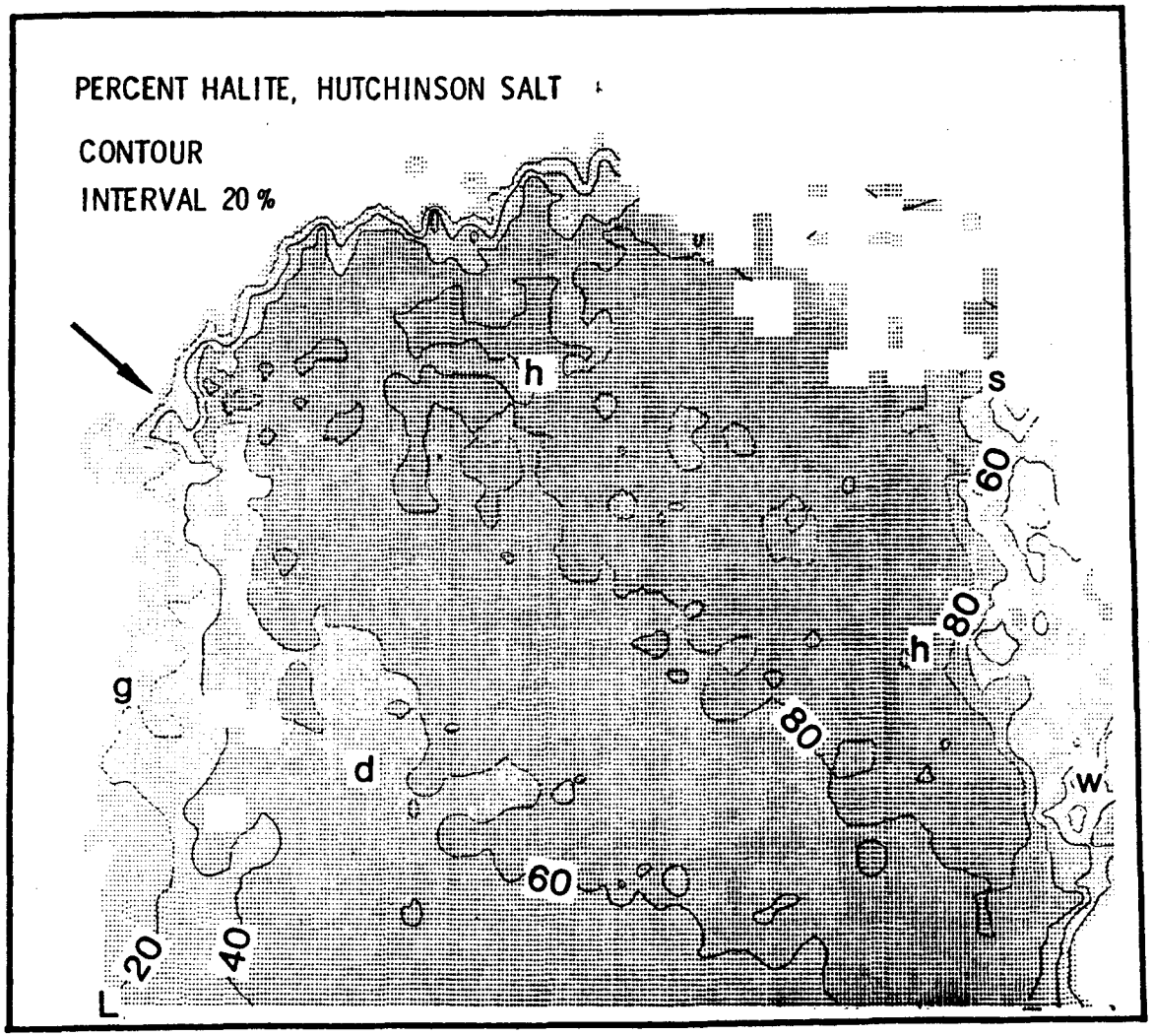


HUTCHINSON
SALT
STUDY

NORTH

MI
0 30
0 50
KM

R14

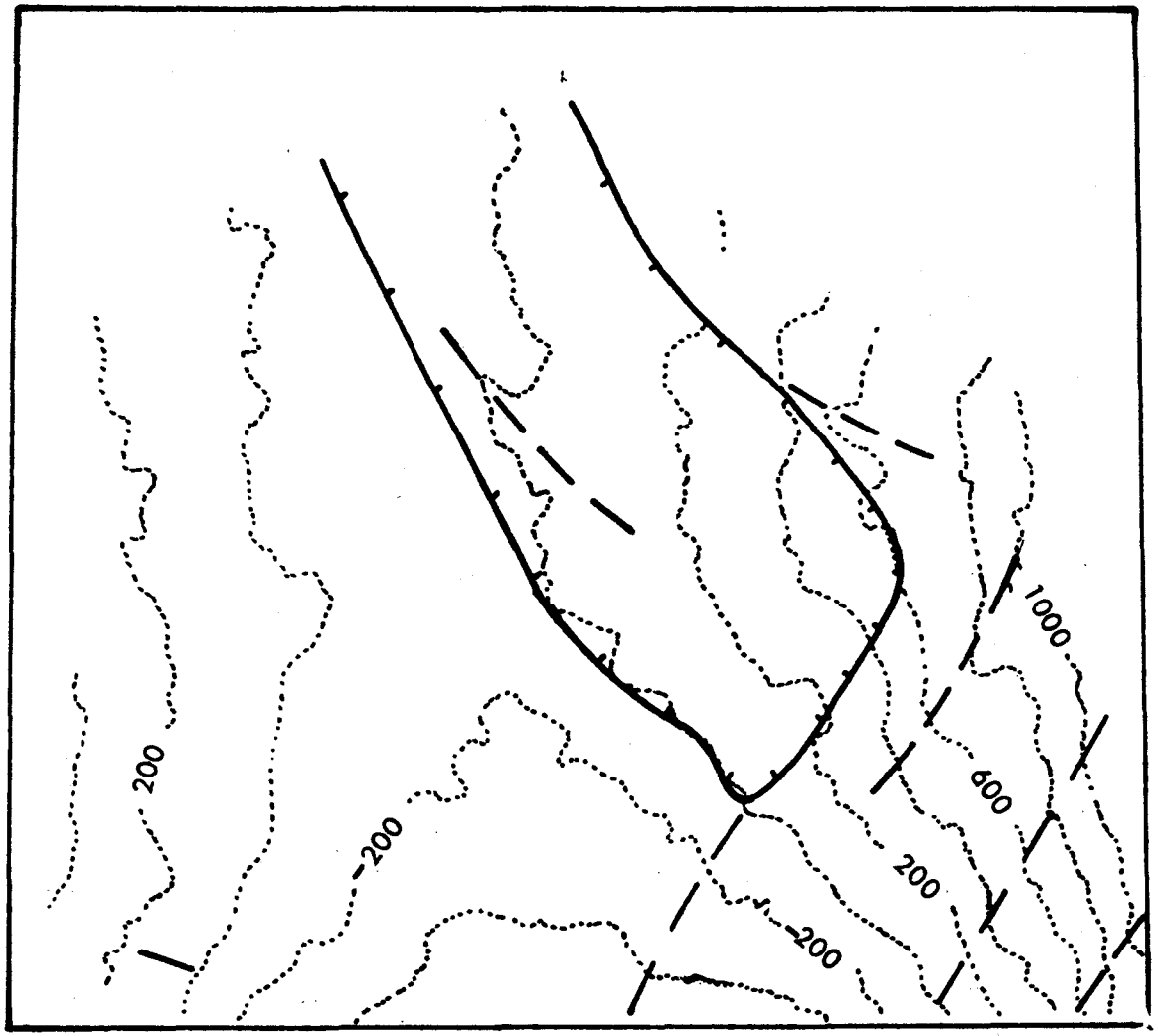


HUTCHINSON
SALT
STUDY

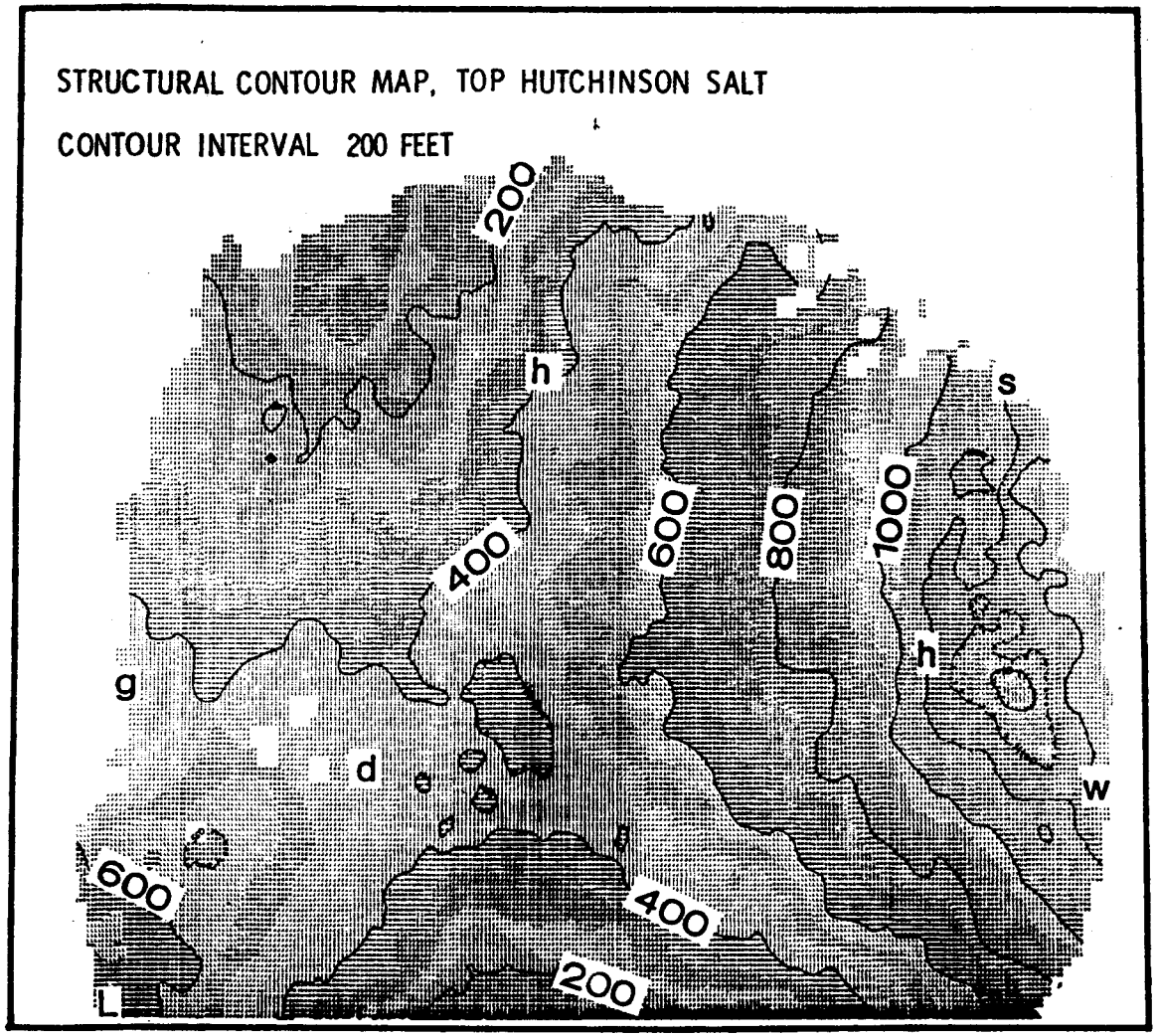
NORTH

MI
0 30
0 50
KM

R15



R17

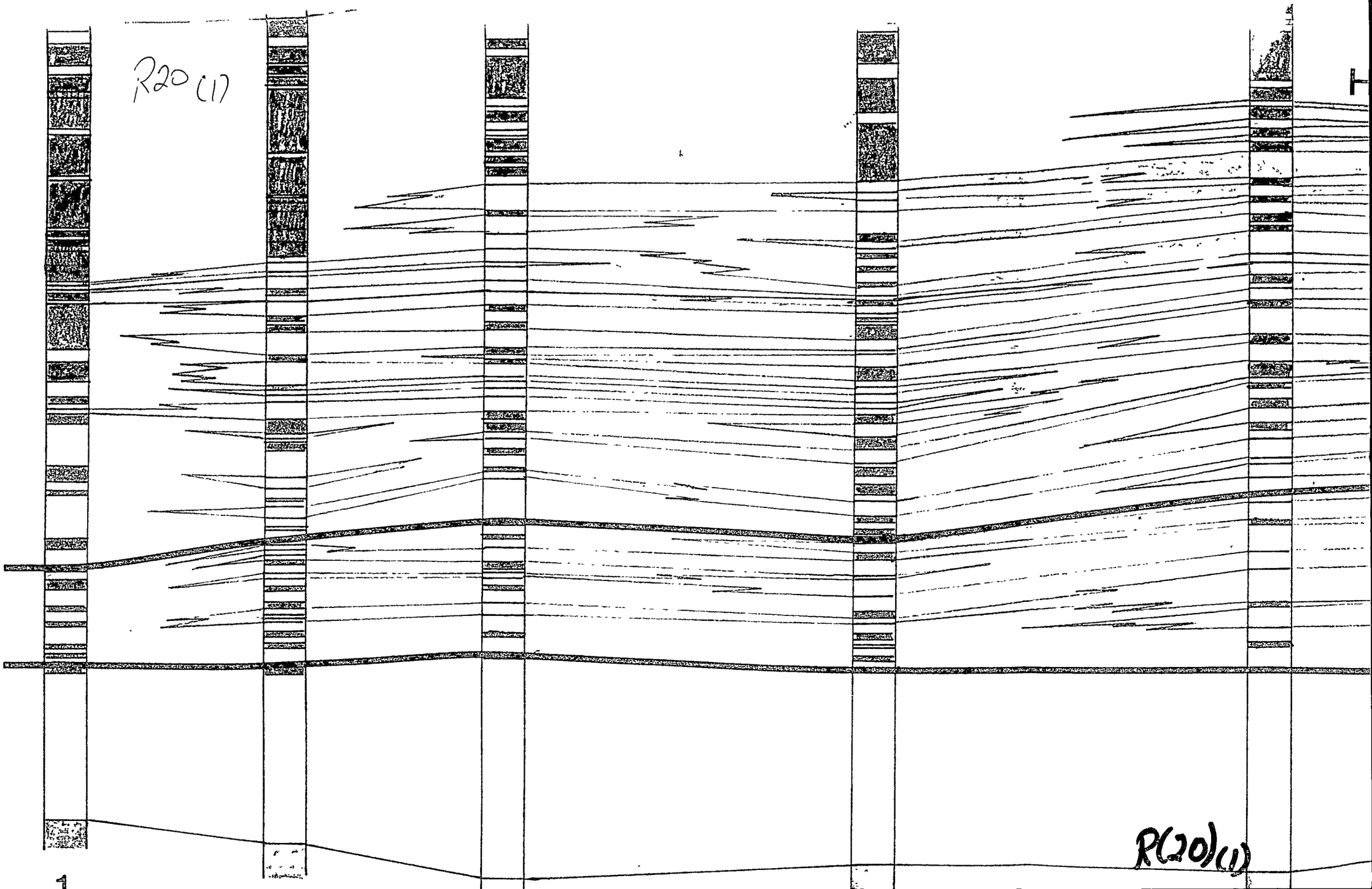


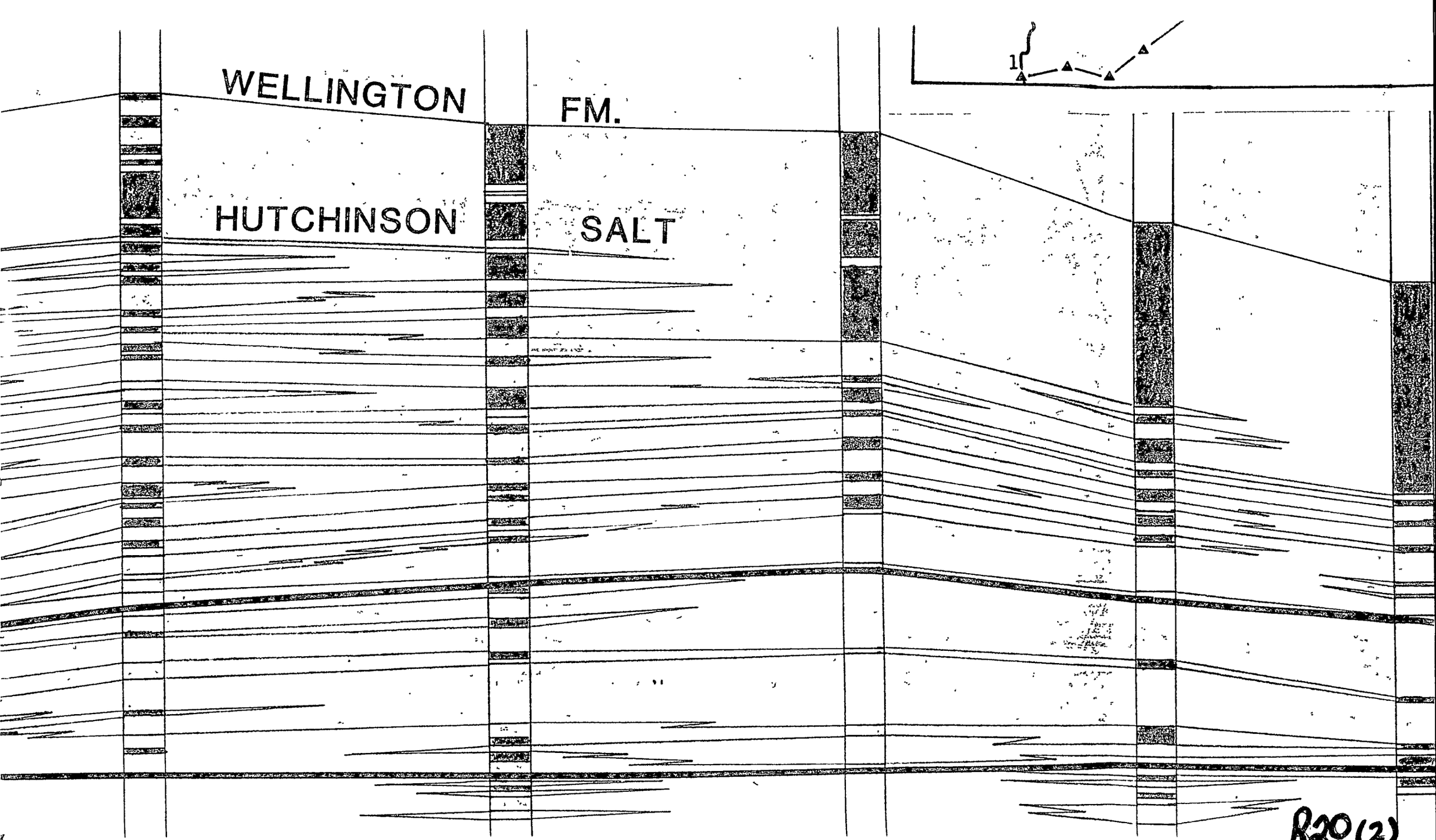
HUTCHINSON
SALT
STUDY

NORTH

MI
0 30
0 50
KM

R18


R20 (1)
R(20)(1)



R20(2)

1. HUTCHINSON SALT WAS INTERMITTENTLY CONNECTED TO SOUTHWEST SEA RESULTING IN CYCLIC EVAPORITE ACCUMULATION AND VARIABLE BROMINE PROFILE.

2. EVAPORITE FACIES ARE LATERALLY EXTENSIVE.

3. LATERAL CHANGE IN FACIES IS GRADUAL.

4. RAPID, PREDICTABLE CHANGE IN VERTICAL SEQUENCE OF EVAPORITE FACIES.

5. THICKER, MORE PURE HALITE PRECIPITATED IN MOST RESTRICTED POSITION OF BASIN; NOT NECESSARILY THE BASIN CENTER.

R22

1. CHANGE TO A MORE ARID CLIMATE.

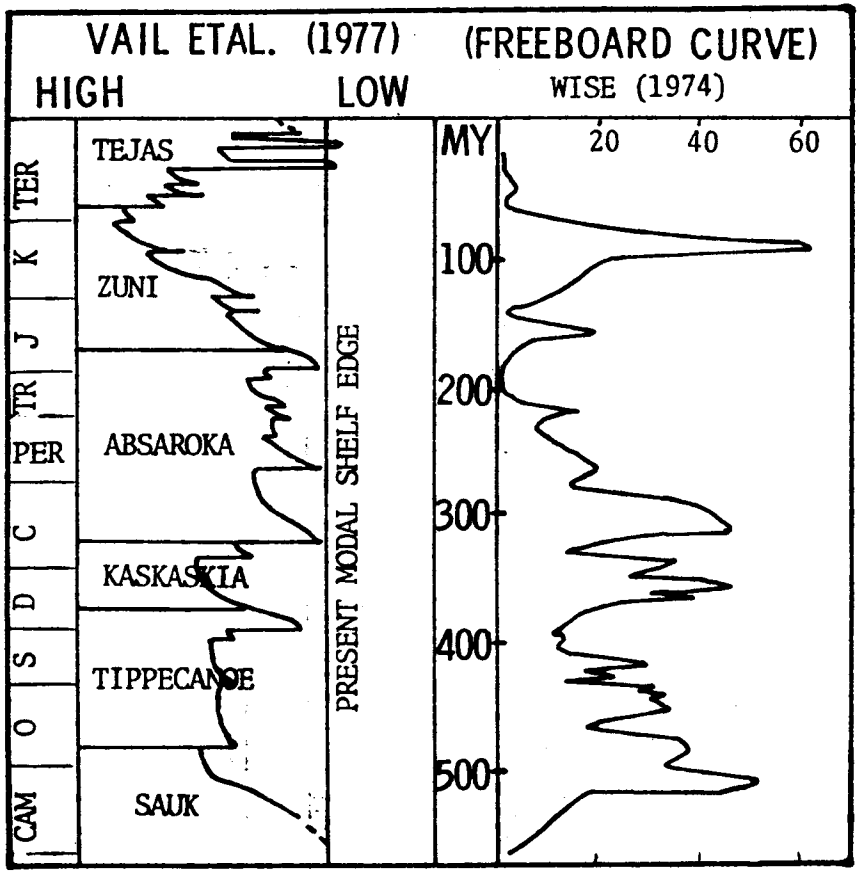
2. SEDIMENT FILLING DALHART BASIN.

3. BUILDUP AND PROGRADATION OF THE CARBONATE SHELF.

R26

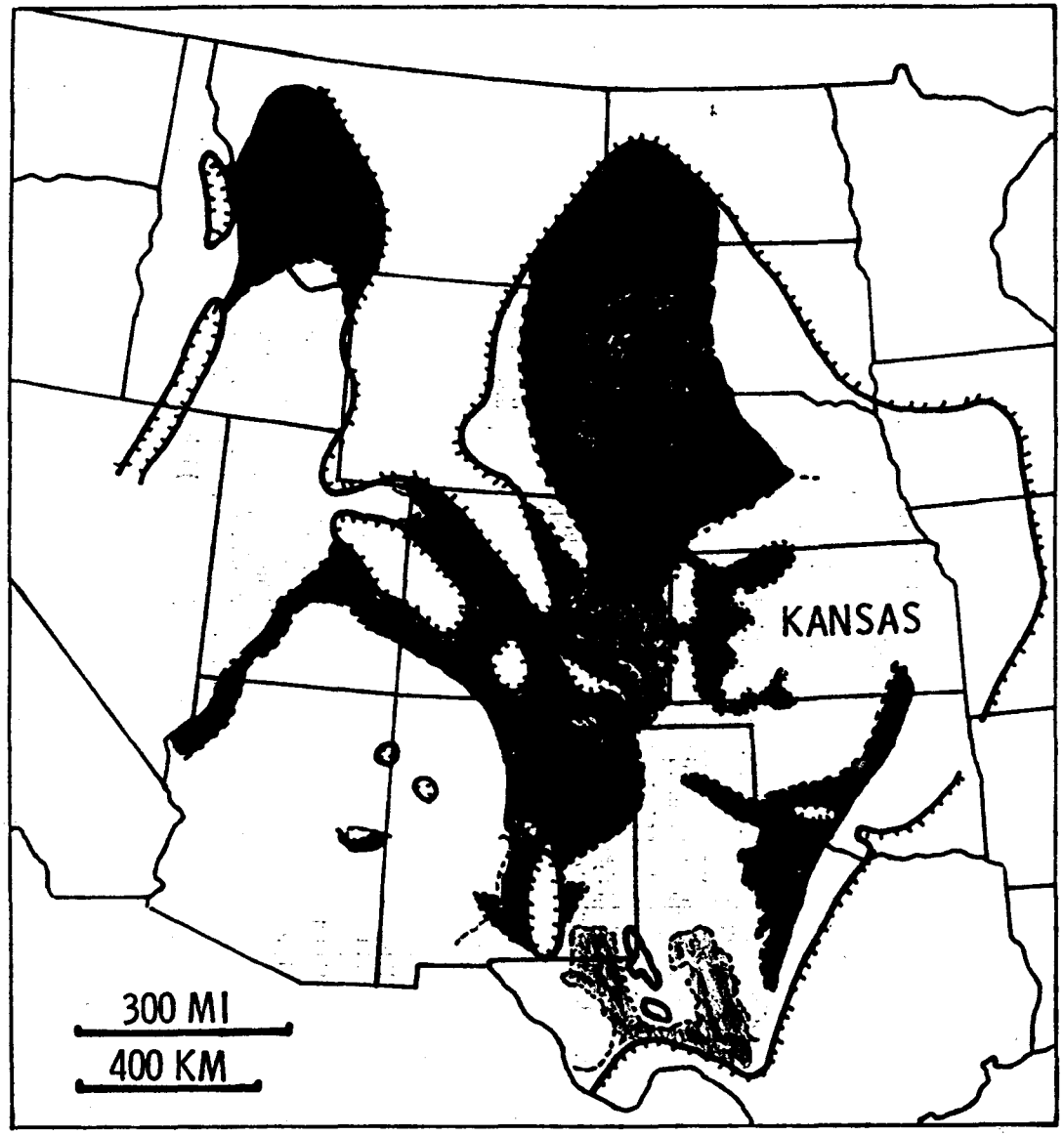
GLOBAL SUPERCYCLES

PERCENT OF FLOODING OF N. A. CRATON



R23

MAJOR SEDIMENT PATTERNS DURING MAXIMUM HIGH STAND OF SEALEVEL, WOLFCAMPIAN

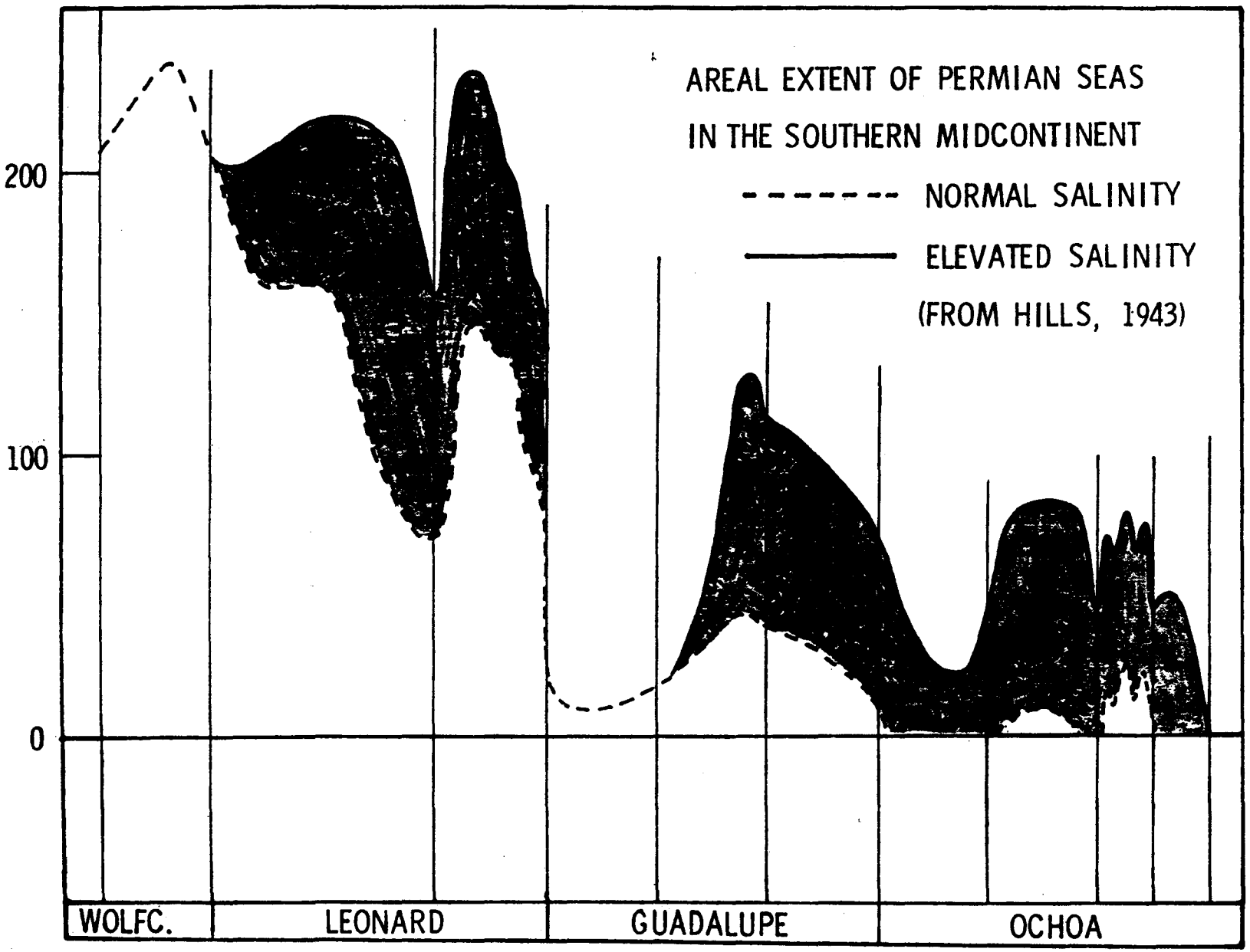


LEGEND

- LS
- DOL
- OM
- SO_4
- Cl
- SS+SH
- LAND

(from McKee etal., 1967)

R24

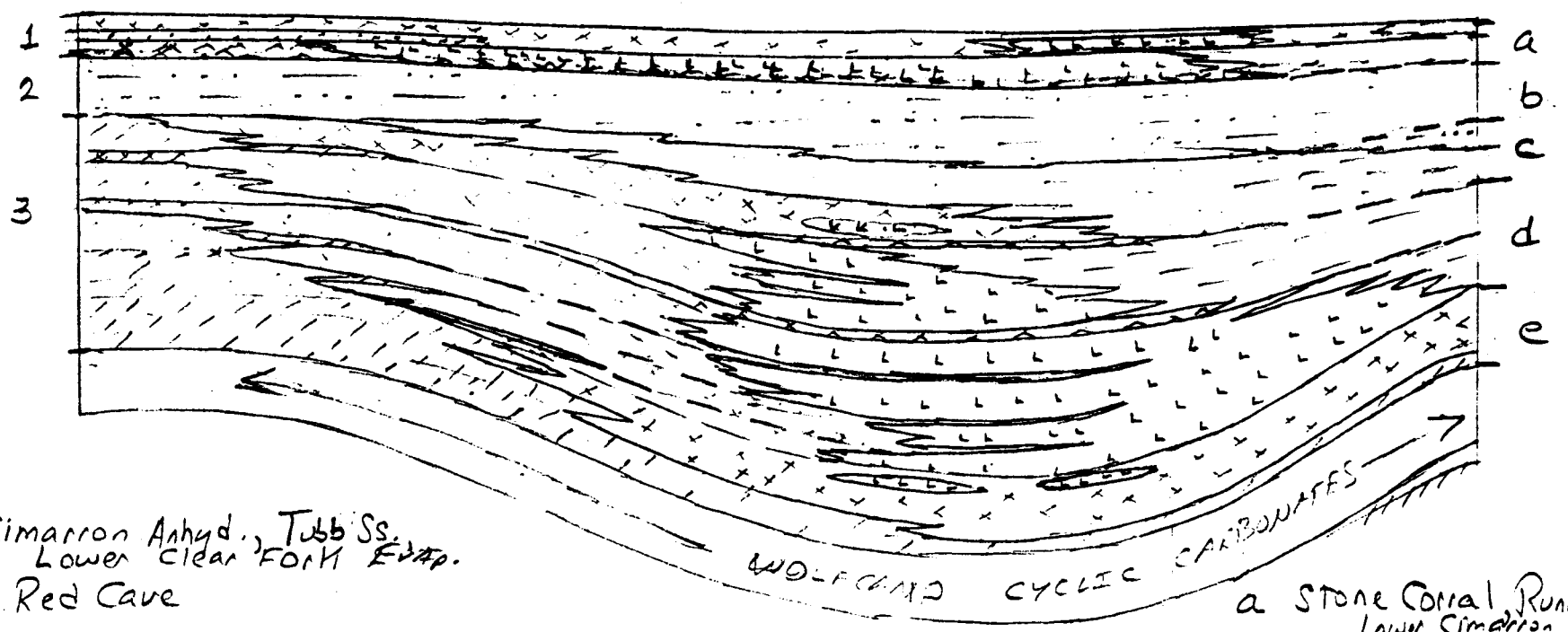

AREAL EXTENT OF PERMIAN SEAS
IN THE SOUTHERN MIDCONTINENT
NORMAL SALINITY
ELEVATED SALINITY
(FROM HILLS, 1943)
200
100
0
WOLFC.
LEONARD
GUADALUPE
OCHOA

R25

SW

TEXAS PANHANDLE | OKLAHOMA | CENTRAL KANSAS

NNE



1 Cimarron Anhyd., Tubb Ss.
Lower Clear Fork Evap.

2 Red Cave

3 Wichita Group

a Stone Corral, Runnymede Ss.
Lower Cimarron Salt

b Ninnescah Shale

c Upper Wellington Sh.

d Hutchinson Salt

e Lower Wellington Anhyd.

INTERPRETIVE CROSS SECTION THROUGH LOWER LEONARDIAN EVAPORITES, WESTERN MIDCONTINENT

R27

R27

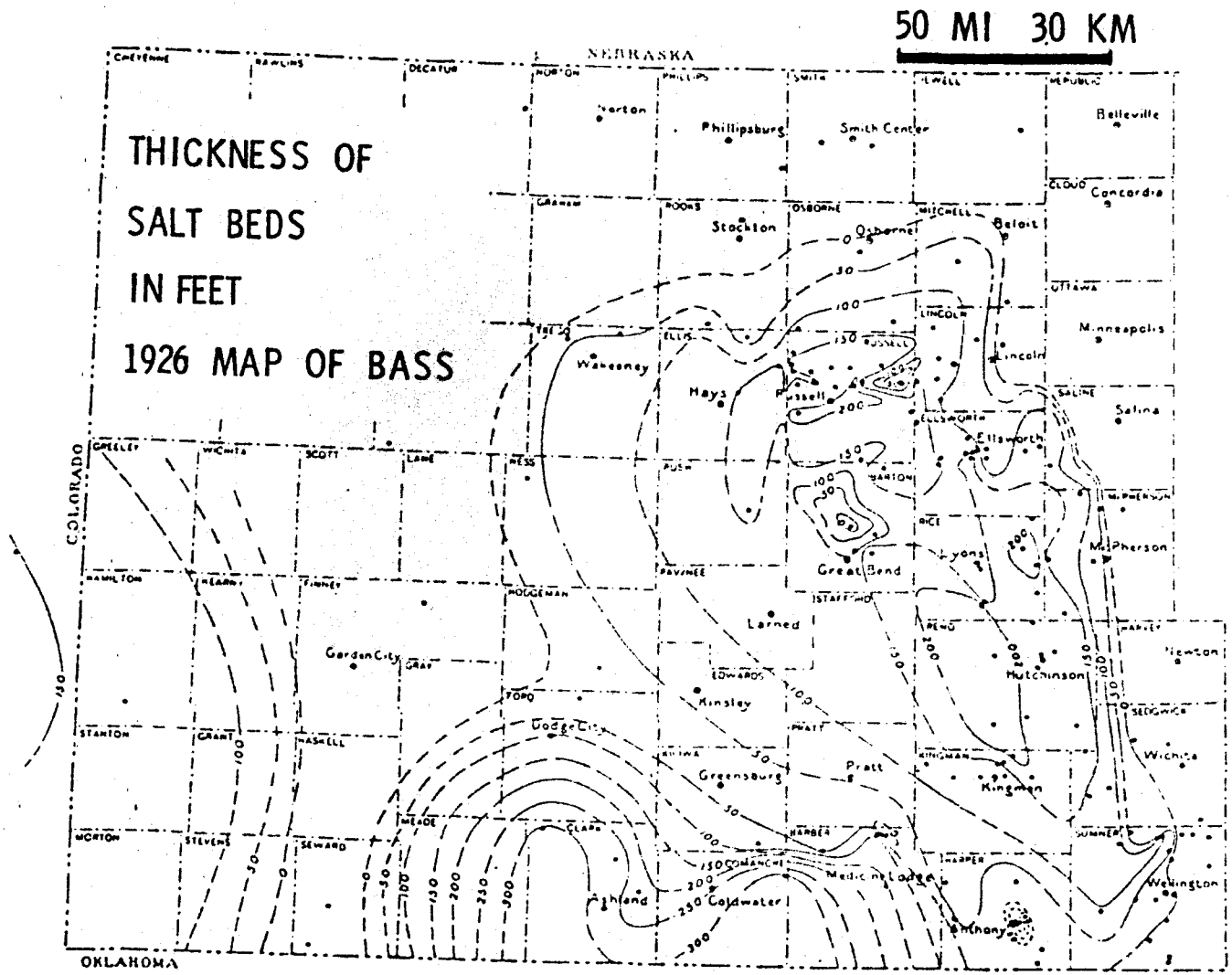
1. EXTENSIVE BRINE BODY WITH A SOUTHWEST CONNECTION TO THE SEA.

2. HALITE ACCUMULATION IN THE MORE RESTRICTED AND MOST SALINE PORTION OF THE BRINE BODY.

3. REGRESSIVE SEDIMENTATION WITH RESULTANT BASIN BASIN FILLING.

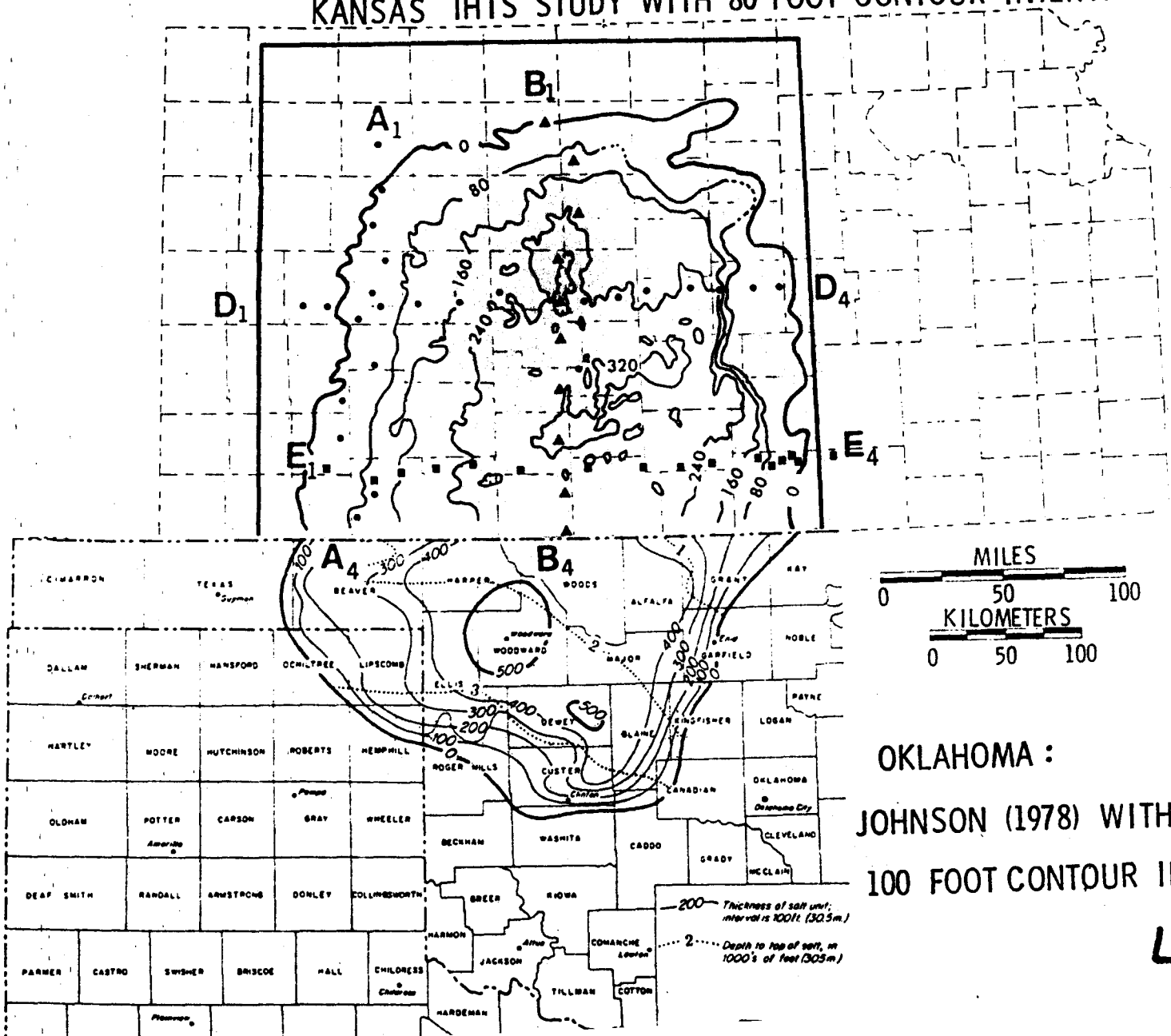
4. UPPER LEONARD DEPOSITION RESULT OF RENEWED TRANSGRESSION OF THE SEA.

R28


50 MI 30 KM
THICKNESS OF
SALT BEDS
IN FEET
1926 MAP OF BASS
NEBRASKA
COLORADO
OKLAHOMA
Norton
Phillipsburg
Smith Center
Belleville
Stockton
Osborne
Beloit
Concordia
Minneapolis
Lincoln
Wakeeney
Hays
Salina
Ellsworth
Great Bend
McPherson
Larned
Hutchinson
Newton
Garden City
Kinsley
Dodge City
Wichita
Greensburg
Pratt
Kingman
Medicine Lodge
Ashland
Coldwater
Wellington
Anthony

LEFT SCREEN

TOTAL SALT ISOPACHS
KANSAS THIS STUDY WITH 80 FOOT CONTOUR INTERVAL

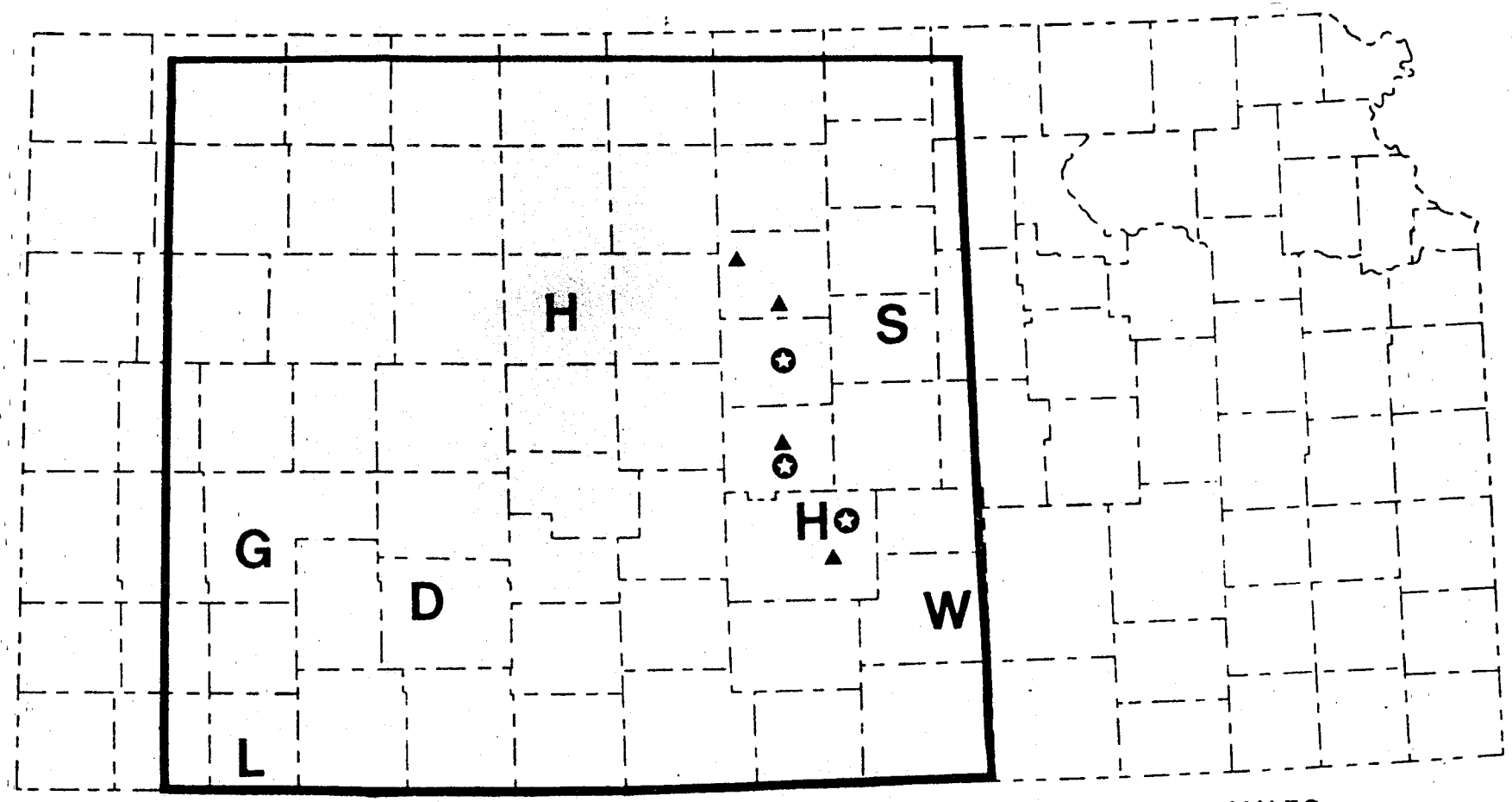


OKLAHOMA :

JOHNSON (1978) WITH

100 FOOT CONTOUR INTERVAL

L2



REFERENCE MAP OF CITIES,
MINES, AND CORES

SALT MINES
SALT CORES

MILES
0 50 100
KILOMETERS
0 50 100

LISTING OF ENTRIES FOR EACH WELL (20)

*NAME
*LOCATION (SPOT)
*ELEVATION
*LOG TYPE
*LOG SCALE
*LOG QUALITY

(LOG PICKS)

*TOP STONE CORRAL
*TOP WELLINGTON MARKER
*TOP HUTCHINSON SALT
*CM 5
*CM 4
*CM 3
*CM 2
*CM 1a
*CM 1
*BASE HUTCHINSON SALT
*TIP NOLANS LN..(CHASE GROUP)

(MEASUREMENTS)

*NET SALT ABOVE CM 3
*NET SALT BELOW CM33
*ESTIMATE AMOUNT TOTAL ANHYDRITE

CALCULATED FROM LOG DATA

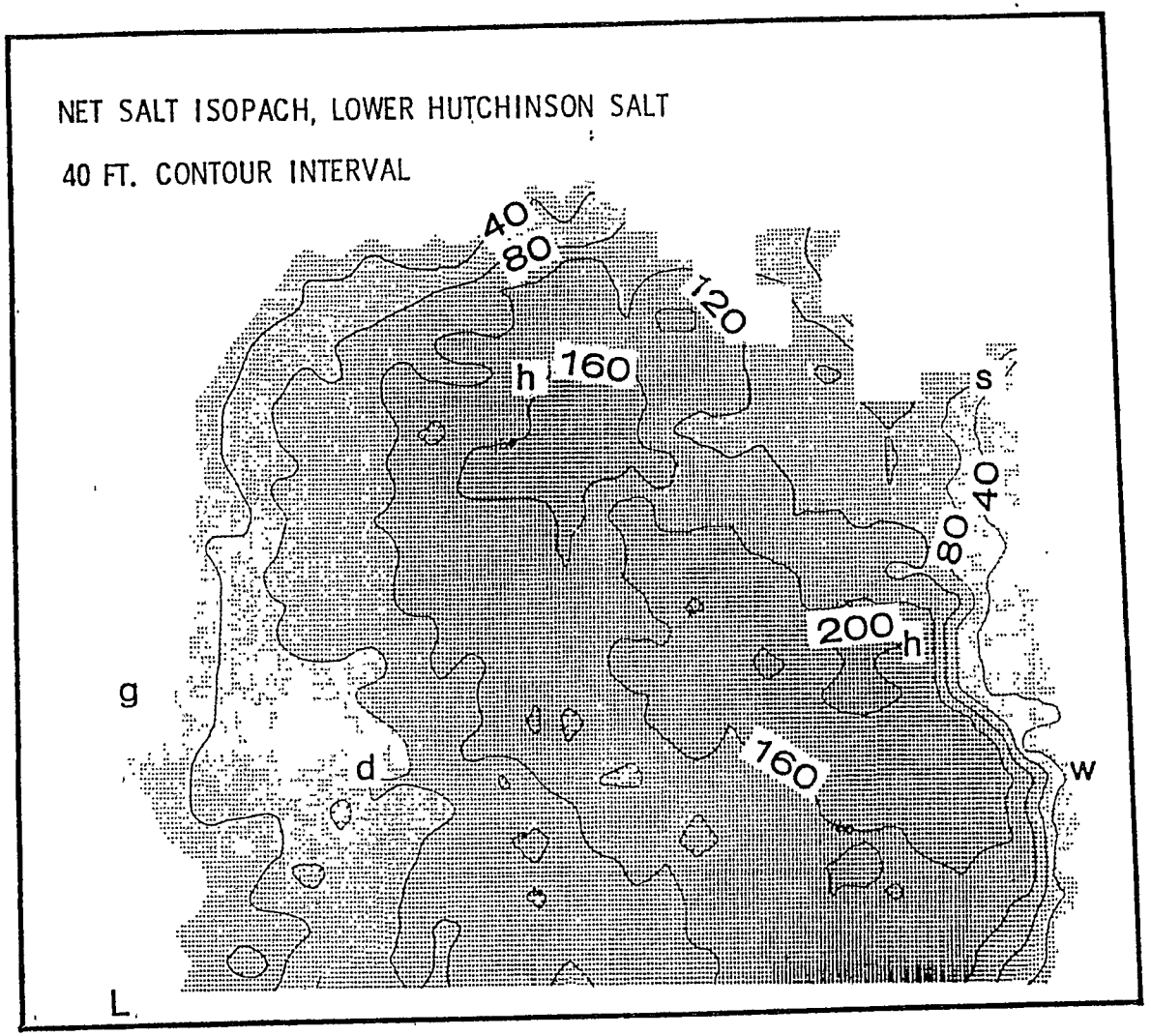
STRUCTURE

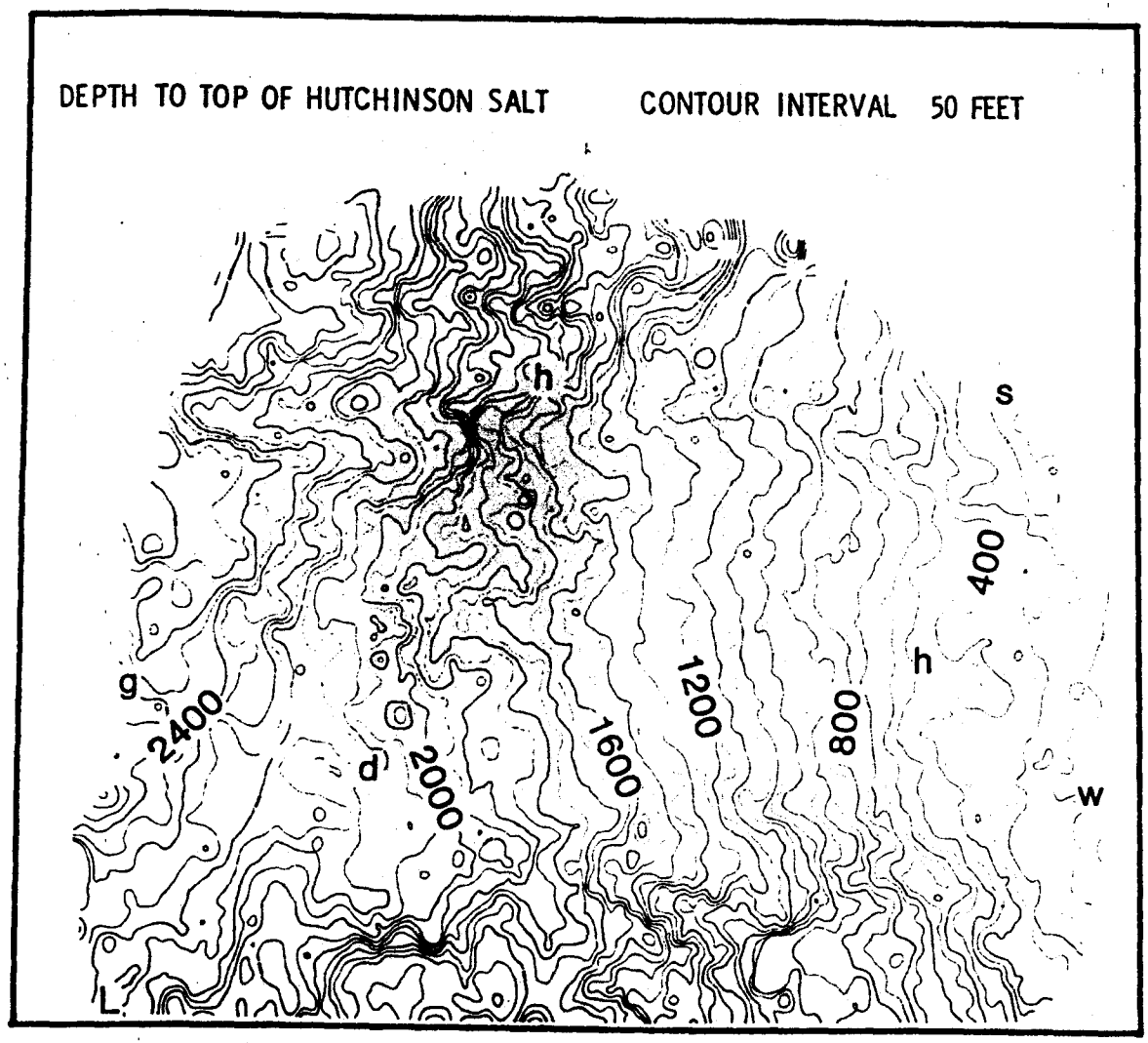
*WELLINGTON SUBSEA
*HUTCHINSON SUBSEA
*NOLANS SUBSEA

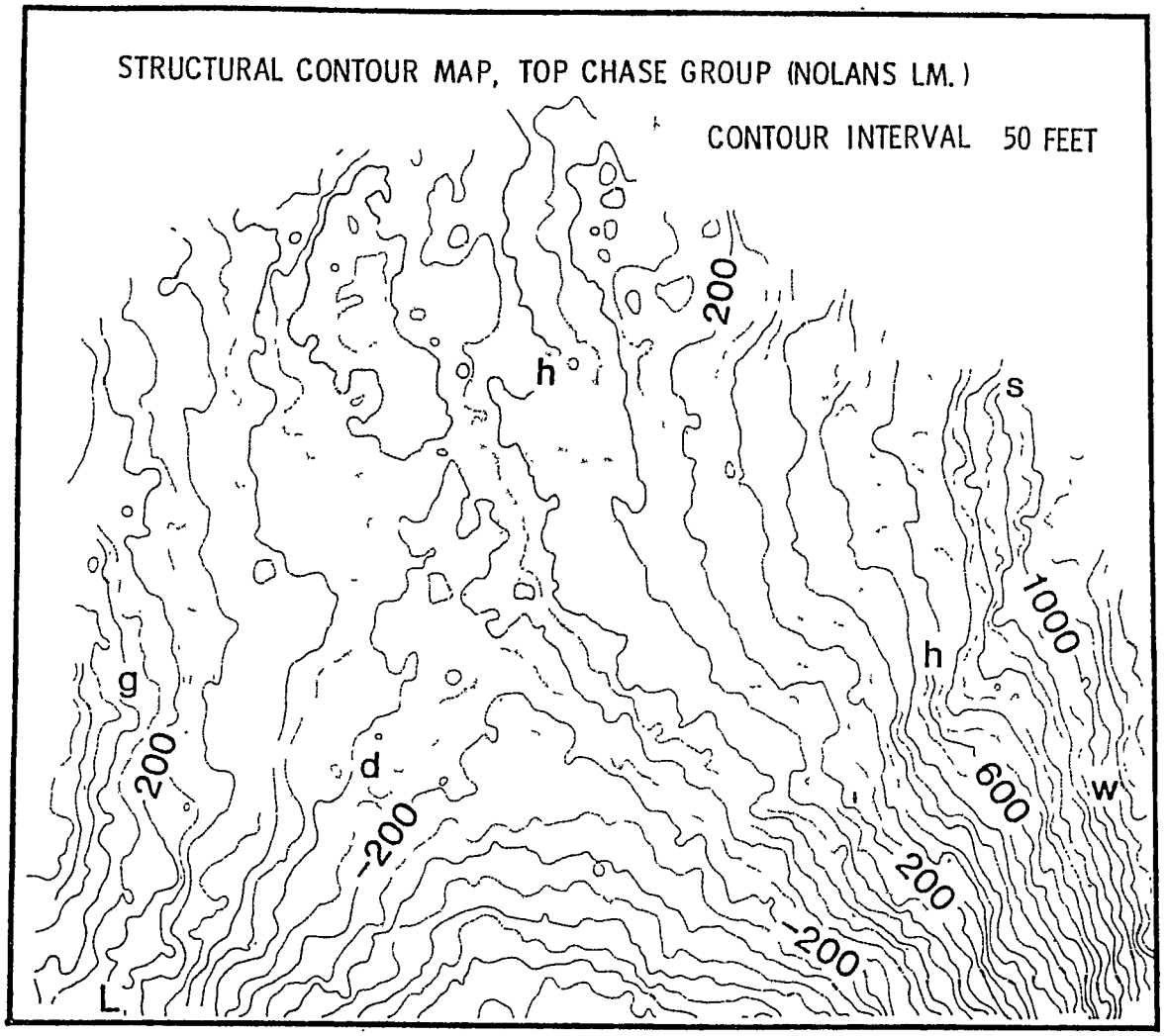
ISOPACH

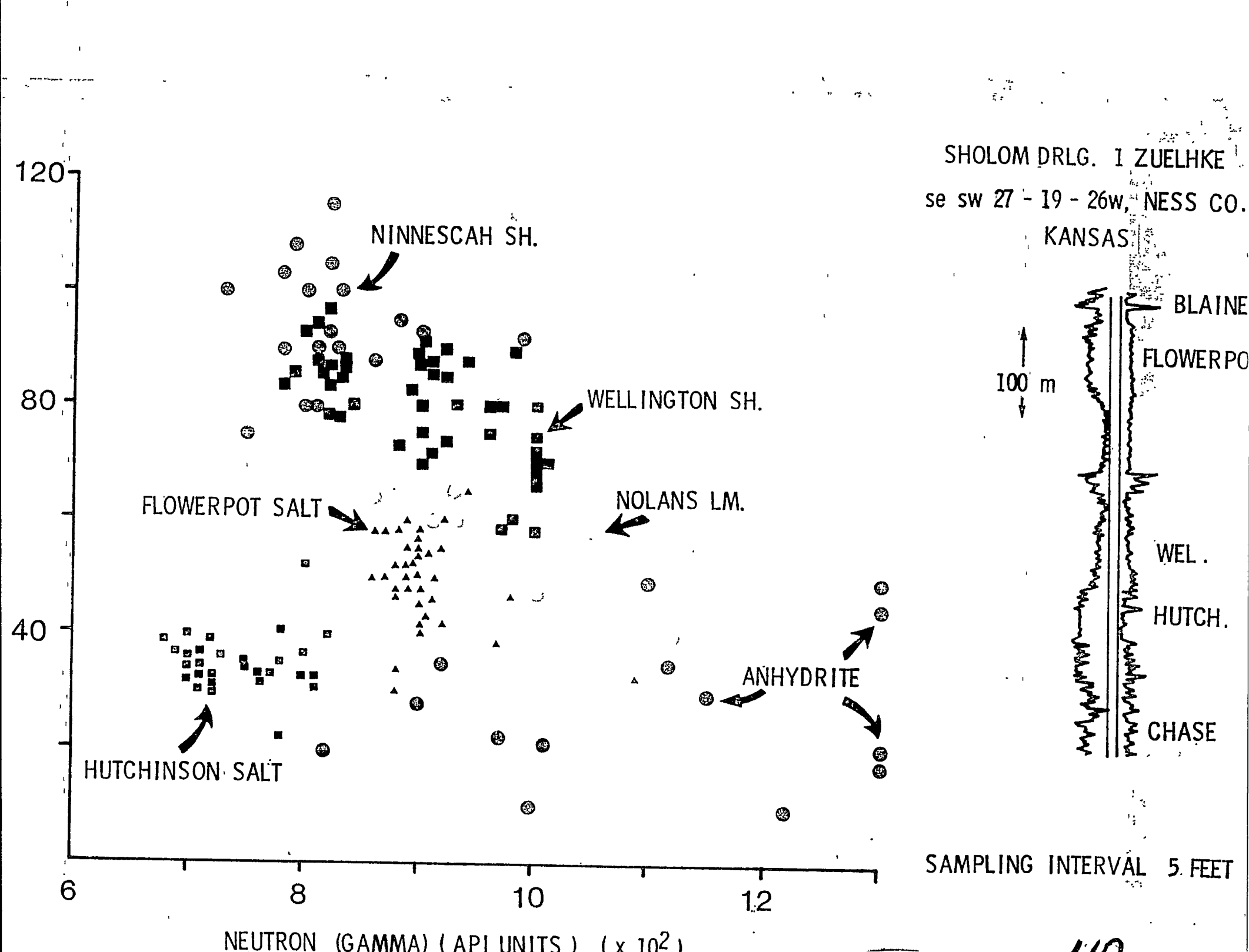
*WELLINGTON TO NOLANS LM.
*TOP HUTCHINSON TO BASE HUTCH.
*TOP HUTCHINSON TO CM 3
*CM 3 TO BASE HUTCHINSON
*TOTAL NET SALT
*SALT PERCENTAGE

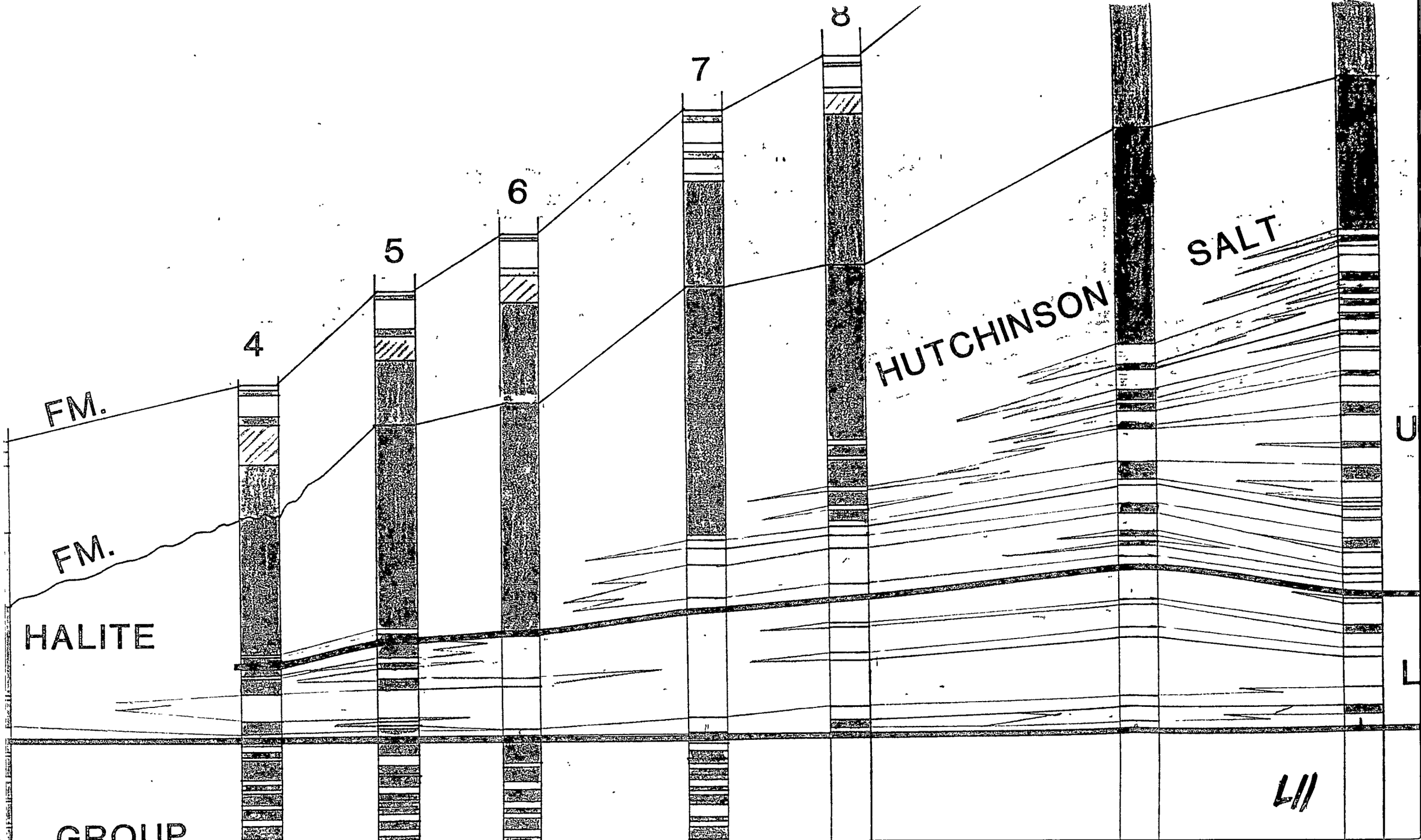
L5


NET SALT ISOPACH, LOWER HUTCHINSON SALT
40 FT. CONTOUR INTERVAL
40
80
120
160
h
s
40
80
200
h
g
d
160
w
L
HUTCHINSON
SALT
STUDY
NORTH
MI
0
30
0
50
KM

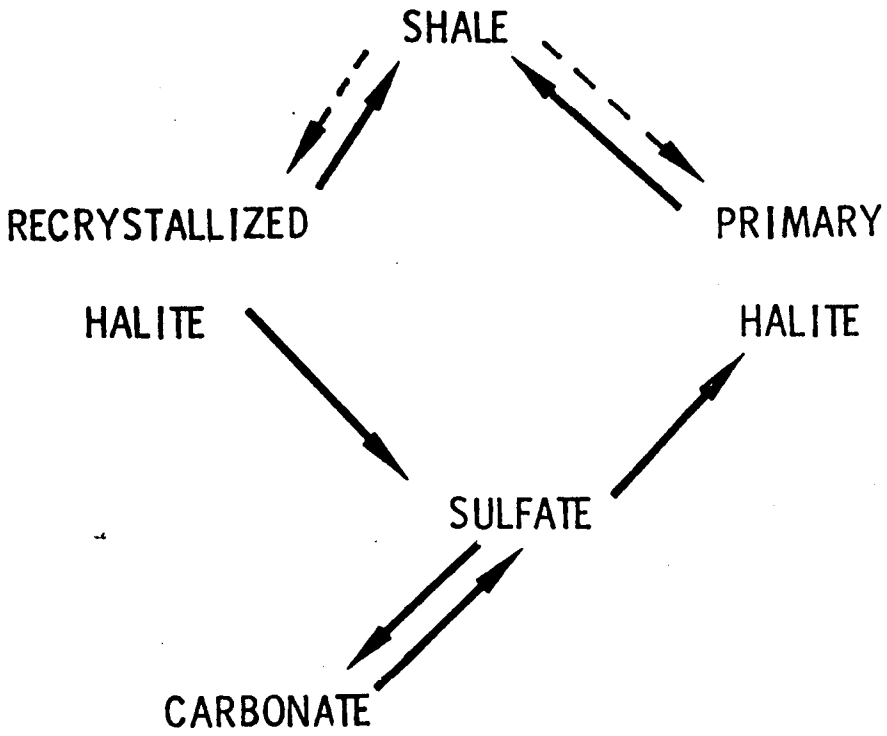

DEPTH TO TOP OF HUTCHINSON SALT
CONTOUR INTERVAL 50 FEET
2400
2000
1600
1200
800
400
HUTCHINSON
SALT
STUDY
NORTH
MI
0
30
0
50
KM


STRUCTURAL CONTOUR MAP, TOP CHASE GROUP (NOLANS LM.)
CONTOUR INTERVAL 50 FEET
200
h
s
1000
h
g
200
d
-200
600
w
200
-200
L
HUTCHINSON
SALT
STUDY
NORTH
MI
0
30
0
50
KM


SHOLOM DRLG. I ZUELHKE
se sw 27 - 19 - 26w, NESS CO.
KANSAS
120
80
40
NINNESCAH SH.
WELLINGTON SH.
FLOWERPOT SALT
NOLANS LM.
ANHYDRITE
HUTCHINSON SALT
6
8
10
12
NEUTRON (GAMMA) (API UNITS) (x 10²)
100 m
BLAINE
FLOWERPO
WEL.
HUTCH.
CHASE
SAMPLING INTERVAL 5 FEET


4
5
6
7
8
FM.
FM.
HALITE
HUTCHINSON
SALT
U
L
GROUP

EMBEDDED MARKOV CHAIN ANALYSIS



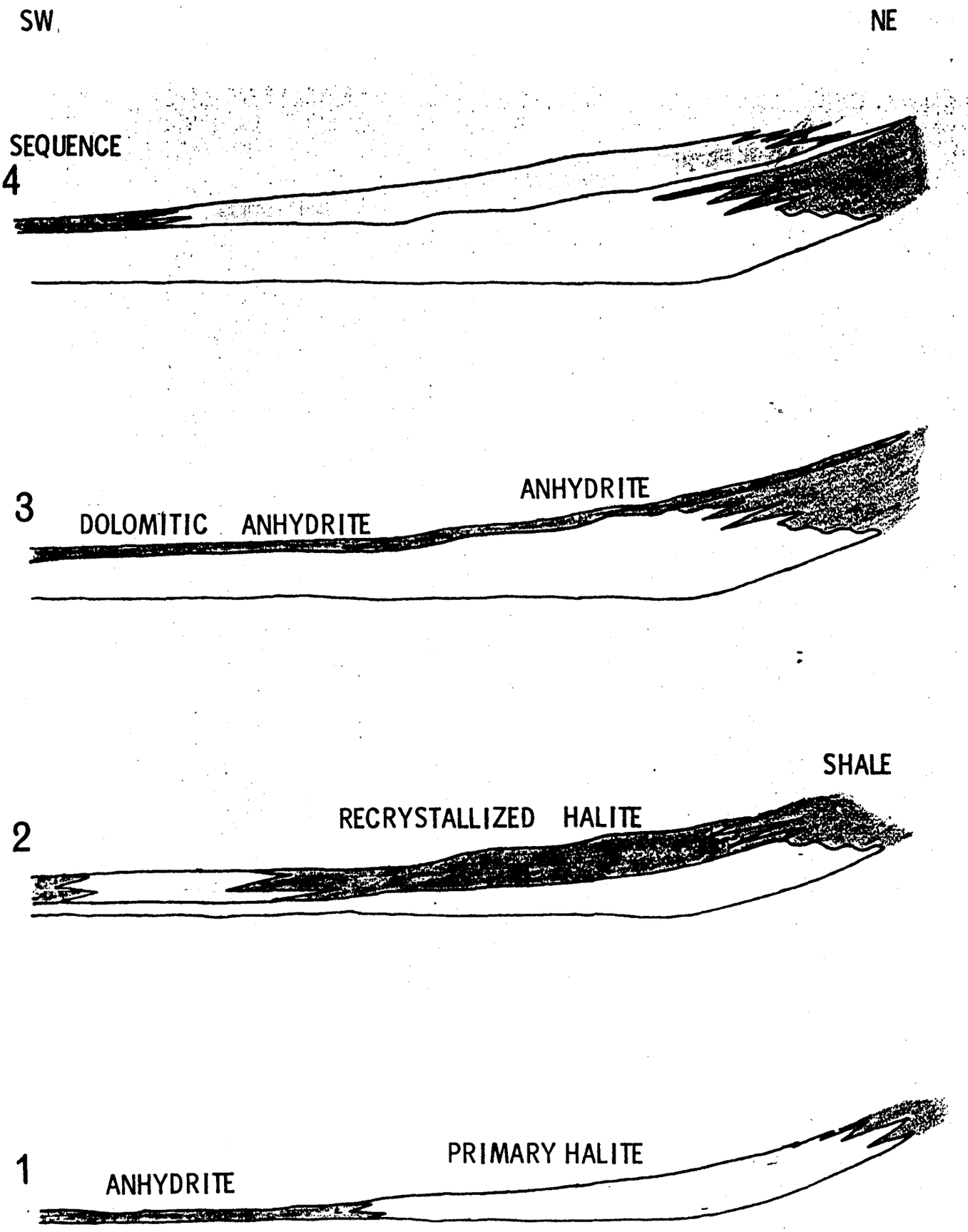
N = 124 $\quad \chi^2_{.05,12} = 19.7$

H_0 : SEQUENCE REPRESENTS FIRST ORDER MARKOV CHAIN

$\chi^2_{CALC} = 24.1$

L12

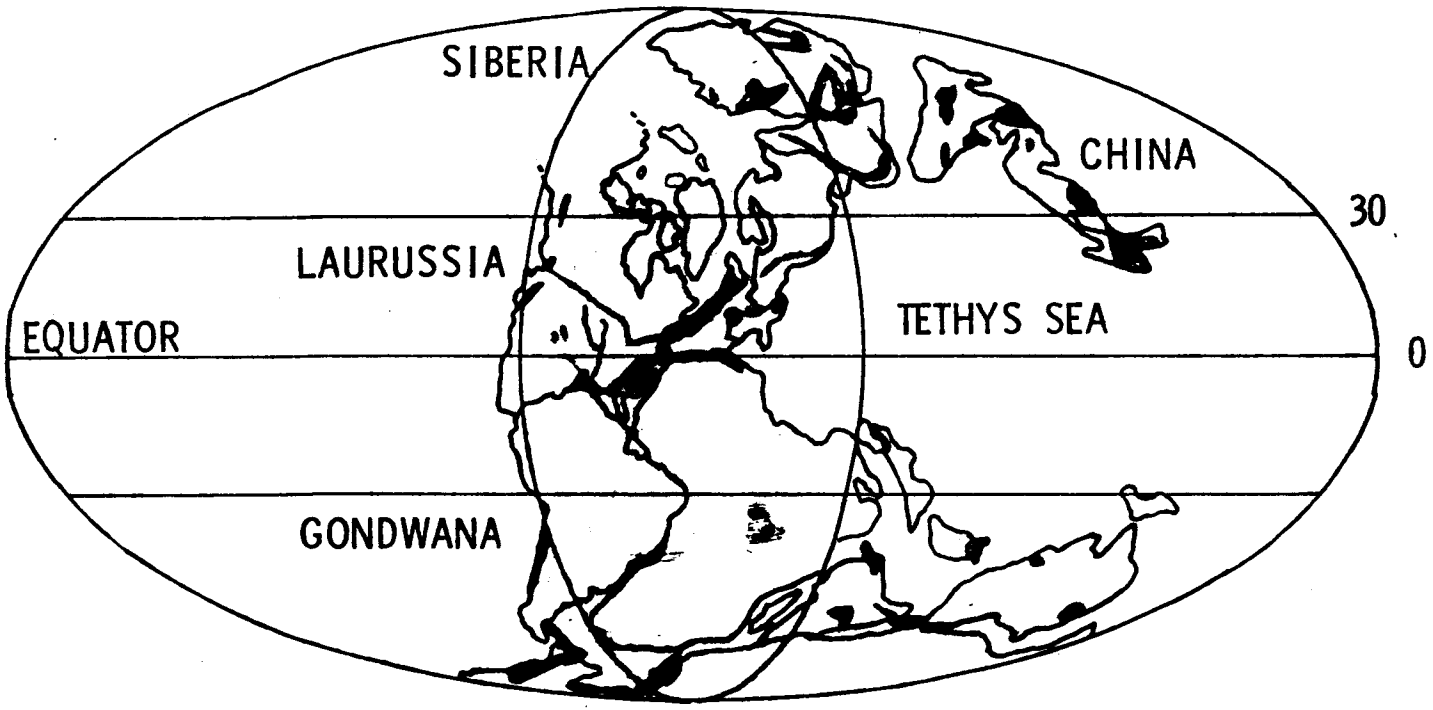
MAJOR EVAPORITE CYCLE DEVELOP



L13

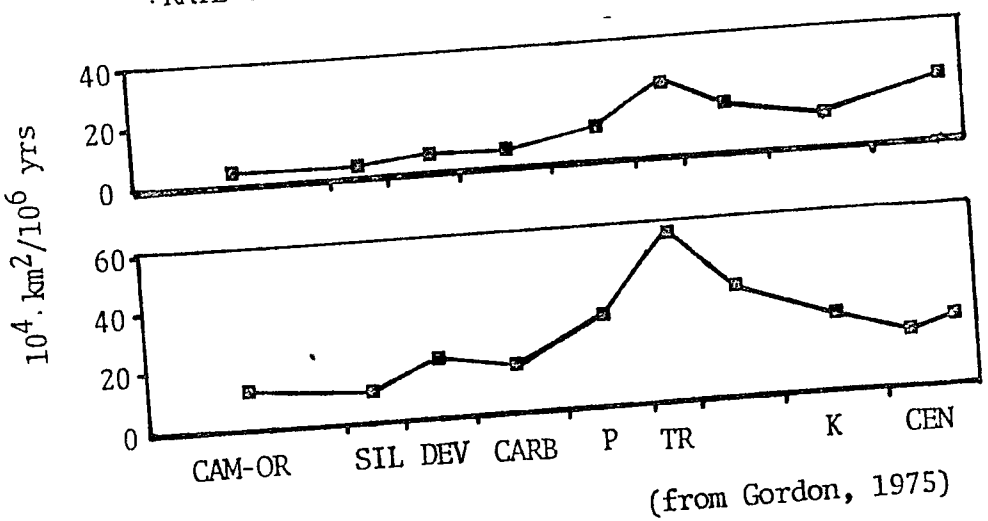
EARLY LATE PERMIAN PALEOGEOGRAPHIC RECONSTRUCTION

BAMBACH ETAL, 1980

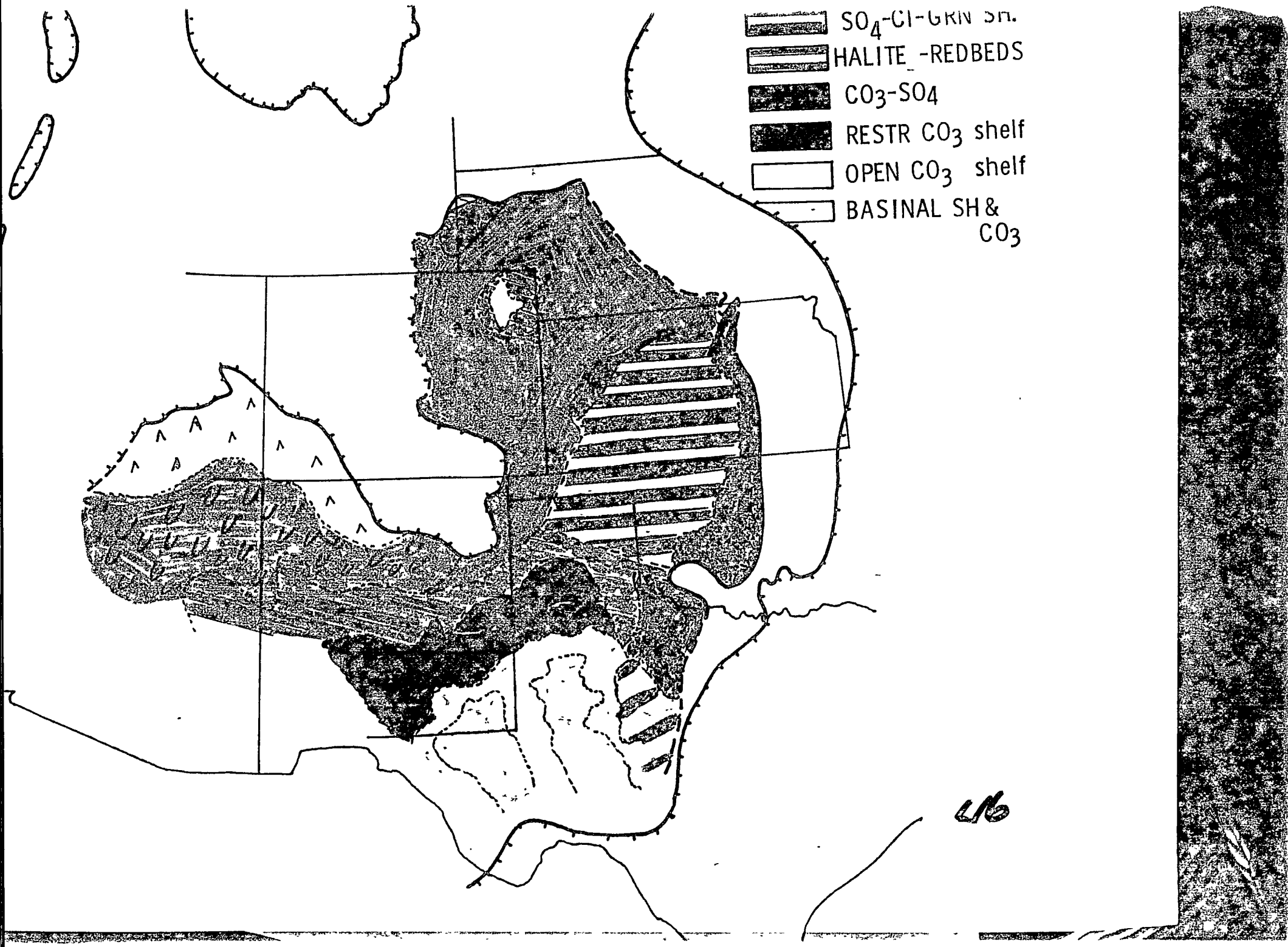


CRATON

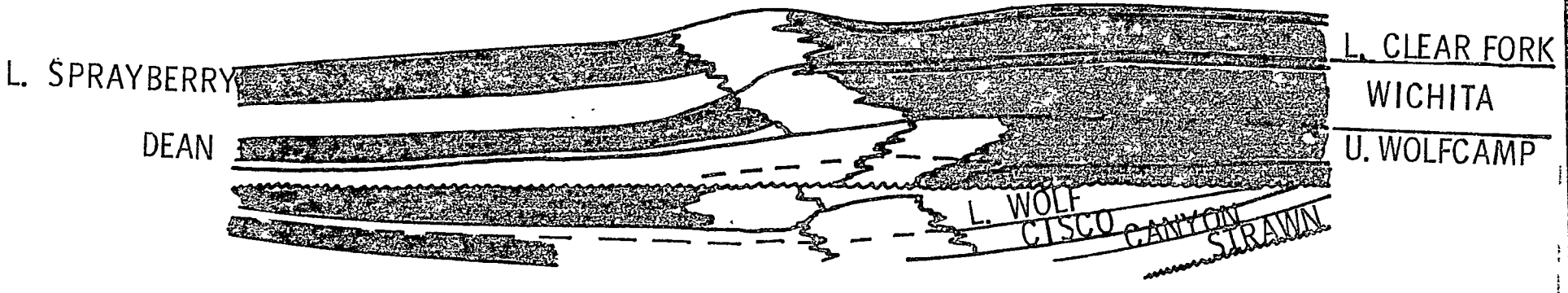
. RATE OF ACCUMULATION OF ANCIENT EVAPORITES



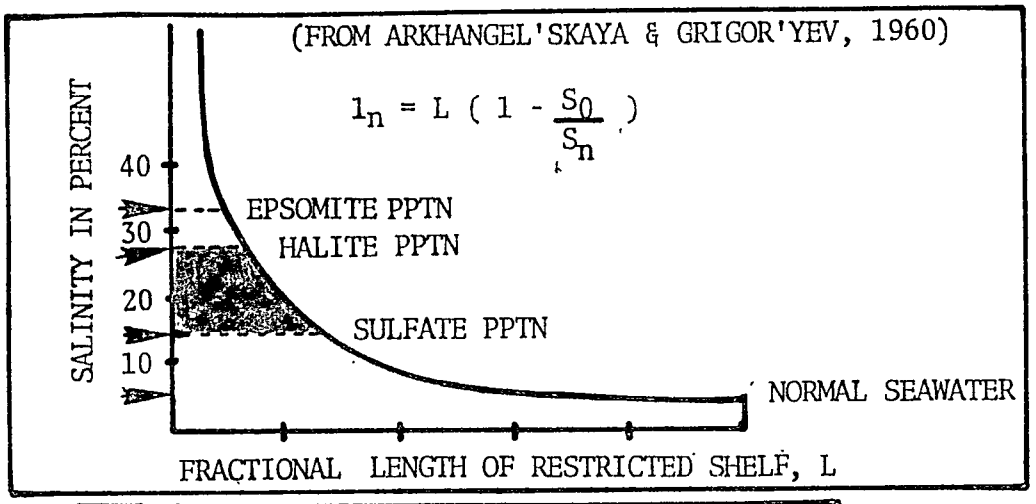
(from Gordon, 1975)

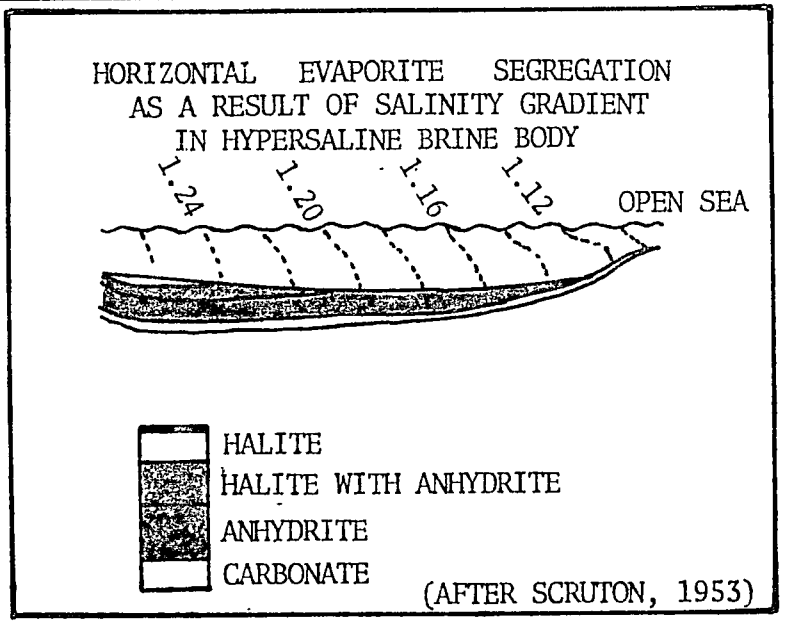

SO_4-Cl-GRN SH.
HALITE -REDBEDS
CO_3-SO_4
RESTR CO_3 shelf
OPEN CO_3 shelf
BASINAL SH & CO_3

SW TO NE DIAGRAMATIC CROSS SECTION OF PERMO-PENN SEDIMENTS IN THE NORTHERN MIDLAND BASIN



(modified from silver and todd, 1969)


(FROM ARKHANGEL'SKAYA & GRIGOR'YEV, 1960)
$l_n = L\left(1 - \frac{S_0}{S_n}\right)$
SALINITY IN PERCENT
40
30
20
10
EPSOMITE PPTN
HALITE PPTN
SULFATE PPTN
NORMAL SEAWATER
FRACTIONAL LENGTH OF RESTRICTED SHELF, L


HORIZONTAL EVAPORITE SEGREGATION
AS A RESULT OF SALINITY GRADIENT
IN HYPERSALINE BRINE BODY
1.24
1.20
1.16
1.12
OPEN SEA
HALITE
HALITE WITH ANHYDRITE
ANHYDRITE
CARBONATE
(AFTER SCRUTON, 1953)