DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 87-351B

105°
104°
103°
102°
42°
41°
40°
39°
38°
HARTVILLE UPLIFT
CHADRON ARCH
DENVER BASIN BOUNDARY
CHEYENNE
WYOMING
NEBRASKA
COLORADO
FORT COLLINS
FRONT RANGE
DENVER
COLORADO SPRINGS
KANSAS
LAS ANIMAS ARCH
DENVER BASIN BOUNDARY
N

Lambert conformal conic projection

SCALE 1:500 000
10 0 10 20 MILES
10 0 10 20 KILOMETERS

EXPLORATION INTENSITY MAP OF THE UPPER CRETACEOUS NIOBRARA FORMATION, DENVER BASIN, COLORADO, NEBRASKA, AND WYOMING

By

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INTRODUCTION

Exploration intensity maps are generated as part of the U.S. Geological Survey Lands Assessment Project to aid in the assessment of National petroleum resources. Illustrated on the Upper Cretaceous Niobrara Formation exploration intensity map are areas of oil and/or gas production and shows, as well as non-producing areas, in the Denver basin. Other exploration intensity maps published for the Denver basin are maps of the Codell, D, and J Sandstones, sandstones and shales of the Pierre Shale, sediments of the Paleozoic section, and a map including all formations in the basin.

Exploration intensity maps are created with data from commercially available petroleum well information databases and database management systems, in conjuntion with database management, statistical, mathematical, and mapping software developed by U.S. Geological Survey personnel. Oil and gas production and show data (through December, 1983) for the approximately 36,000 Denver basin drill holes are retrieved from the Petroleum Information Corporation (PI) Well History Control System (WHCS) computer database. The retrieved drill hole data are then entered into a set of fortran programs developed by the U.S.G.S., which code the drill holes for production rank by geologic formation, divide the basin into grid cells, analyze production and show data for the one or more drill holes within each cell, and assign the grid cell one symbol representing the occurrence of oil and/or gas production, show, or lack of hydrocarbon occurrence. The assigned symbol represents an arbitrary hierarchical ranking in which petroleum production is assigned a higher rank than a hydrocarbon show, which is ranked above non-producing, non-show drill holes. Oil and gas production is ranked higher than oil, which in turn is ranked above gas production. A grid cell with 3 drill holes, one with a test show of gas, another with oil and gas production, and the third a dry hole would have an oil and gas production symbol.

This resource appraisal tool has a number of advantages, including the following;

1) Analysis by grid cell allows for a number of possible map scales. A 1:500,000 scale drill hole map would be almost illegible in areas of high drilling density, and production trends would not be discernable.
2) The use of computer databases and statistical and mapping programs saves considerable time over manual production map construction.
3) Different types of maps can be plotted from one data file; including maps at different scales, showing production and/or exploration cells for one or multiple formations, and using colors to differentiate between oil and/or gas production or shows.
4) Data files, statistical data, and plot files can be stored on computer disk or tape for future reference.
5) The grid cell program tends to smooth database errors, however the accuracy of the intensity map is dependent upon the quality of drill hole information supplied by the operators and input to the database by PI.

COMPUTER ANALYSIS AND MAPPING PROCEDURES

DRILL HOLE DATA RETRIEVAL SORTING AND RANKING

Drill hole location, American Petroleum Institute (API) number, elevation, total depth, and production and show test data are retrieved from the Petroleum Information Corp. WHCS database using PI's TECH/SYS database management system. The retrieved drill hole data file is entered into a fortran sorting program (Higley, 1986) which, in each drill hole, assigns a hierarchical code to each formation in which hydrocarbon shows are present. The assigned code is based on the type of hydrocarbon occurrence present and the type of test run in the drill hole, although map symbols representing the test type were not used. An arbitrary rank is assigned whereby oil and gas shows are given higher rank than oil shows, which are in turn ranked higher than gas shows or undifferentiated shows. The sorting program output file contains the drill hole production and show data for each formation listed in the retrieval, and is ready for entry into an unpublished grid cell calculating program developed by David Root of the U.S. Geological Survey.

GRID CELL CALCULATION

Drill hole location, production status, and arbitrary hydrocarbon rank from the above sorting program are entered into Root's software package, which divides the area of the data set into fractions of a base latitude of approximately 1/2 mile spacing, producing approximately 1/4 mi^2 grid cells. Grid cells can be ranked for the entire data set or for one or more specific formations within the data set, as is the case of this map. Arbitrary petroleum rank for drill holes within the cell are analyzed, and one symbol representing the highest rank of production or show is plotted for each cell on the final intensity map.

The hierarchical petroleum ranking is as follows:

1) DRILLED GRID CELLS

Producing grid cells

A) Producing grid cells are those that contain at least one drill hole producing oil and gas, oil, or gas from carbonates of the Niobrara Formation.

Dry grid cells

B) If the highest rank of Niobrara hydrocarbon occurrence within a cell is for a show of oil and/or gas then a map symbol representing the type of show is plotted. The show rank is as follows: oil and gas show, oil show, gas show, and undifferentiated show, respectively. An undifferentiated show is one in which a hydrocarbon show was detected in the drill hole but the type of show was not recorded by the operator.

C) If all drill holes penetrating the Niobrara Formation within a cell are non-productive with no shows then a map symbol representing a dry cell is assigned.

2) UNDRILLED GRID CELLS

Undrilled grid cells are those which contain no drill holes penetrating the Niobrara Formation. Proximity and location relative to drill holes in adjoining grid cells results in assignment of undrilled grid cells to the arbitrarily defined gas infill, "potentially productive", or "explored" cell categories.

Gas infill grid cells

A) Gas well spacing is generally greater both than oil well spacing and the program grid spacing of approximately 1/2 mile. Based on a 1 mile spacing for the Denver basin, areas in which undrilled grid cells are surrounded on at least 3 sides by gas producing cells are infilled with a computer gas infill routine. A gas production infill map symbol is assigned to these grid cells.

"Potentially productive" grid cells

The "potentially productive" category indicates that an undrilled grid cell is bounded by 3 or more drilled, productive grid cells. This category is used for hydrocarbon assessment purposes and does not represent the actual presence of potentially productive areas.

B) Undrilled grid cells surrounded on three sides by oil and gas producing cells are "potentially productive" for oil and gas. Similarly, "potentially productive" grid cells for oil are surrounded by 3 or more oil productive grid cells. "Potentially productive" gas grid cells are assigned a gas infill map symbol.

"Explored" grid cells

C) This assessment category is used primarily to identify areas which have been actively explored and evaluated. Undrilled cells are defined as "explored" when the center of the grid cell or cells lie within a set of drill holes which are located within a circle of chosen radius. The chosen radius for the Denver basin is 1 mile.

MAP GENERATION

The output from the exploration intensity retrieval and grid cell calculation programs can be used a a variety of commercially available statistical and mapping packages. This map was generated using the U.S. Geological Survey's Regional Geophysical Software Library (RGSL) mapping software package (Evenden, 1975).

ACKNOWLEDGEMENTS

David Root of the U.S. Geological Survey developed the fortan software programs for calculating grid cells.

SELECTED REFERENCES

Evenden, G. I., 1975, A general purpose contouring system, U.S. Geological Survey Open-File Report 75-317, 108 p., 8 figs.

Higley, D. K., 1986, Fortran sorting program to code hydrocarbon production and show data using well data from Petroleum Information's Well History Control System, U.S. Geological Survey Open-File Report 86-437, 28 p.

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EXPLANATION

DRILLED GRID CELLS

PRODUCING CELLS:

- ⧖ OIL AND GAS PRODUCING
- □ OIL PRODUCING
- ▽ GAS PRODUCING

DRY CELLS:

- ✳ OIL AND GAS SHOW
- × OIL SHOW
- \+ GAS SHOW
- — SHOW: TYPE UNKNOWN
- ◇ NO SHOW

UNDRILLED GRID CELLS

GAS INFILL CELLS:

- △ ADDED AS PART OF THE GAS INFILL COMPUTER ROUTINE

"POTENTIALLY PRODUCTIVE" CELLS:

- Y SURROUNDED ON AT LEAST 3 SIDES BY OIL AND GAS PRODUCING CELLS (⧖)
- ○ SURROUNDED ON AT LEAST 3 SIDES BY OIL PRODUCING CELLS (□)
- △ SURROUNDED ON AT LEAST 3 SIDES BY GAS PRODUCING CELLS (▽) OR CELLS ADDED BY A GAS INFILL ROUTINE

"EXPLORED" CELLS:

- • SURROUNDED BY 3 OR MORE DRILL HOLES LYING WITHIN A 1 MILE RADIUS CIRCLE