

Modeling of an Unconventional Gas Accumulation Taking into Account Spatial Correlation, Greater Natural Buttes, Utah*

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Abstract

The Greater Natural Buttes tight sandstone field, Uinta Basin, northeast Utah, is an unconventional gas accumulation that started production in the early 1950s from the Upper Cretaceous Mesaverde Group and three years later was extended to the Eocene Wasatch Formation. By 2007, with the exclusion of 1150 dry wells, we estimate that final recovery from the existing 2500 producing wells will be 1.7 trillion cubic feet (TSCF). The use of estimated ultimate recovery (EUR) per well as the main source of information is typical of continuous accumulation assessments. Each calculated recovery value has an associated drainage area that generally varies from well to well and that can be mathematically subdivided into elemental subareas of constant size and shape called cells. Recovery per 5-acre cells at Greater Natural Buttes shows spatial correlation; hence statistical approaches that ignore this correlation when inferring EUR values for untested cells do not take full advantage of all the information contained in the data. More critically, resulting models do not match the style of spatial EUR fluctuations observed in nature. This study takes a new approach by applying spatial statistics to model geographical variation of cell EUR, taking into account spatial correlation and the influence of fractures. We applied sequential indicator simulation to model non-productive cells, while spatial mapping of cell EUR was obtained by applying sequential Gaussian simulation to provide multiple versions of reality (realizations) having equal chances of being the correct model. For each realization, summation of EUR in cells not drained by the existing wells allowed preparation of a stochastic prediction of undiscovered resources, which range between 2.6 and 3.4 TSCF with a mean of 2.9 TSCF for Greater Natural Buttes. A second approach illustrates the application of multiple-point simulation to assess a hypothetical frontier area for which there is no production information but which is regarded as being similar to Greater Natural Buttes.

References

Johnson, R.C., and S.B. Roberts, 2003, The Mesaverde total petroleum system, Uinta-Piceance Province, Utah and Colorado, *in* USGS Uinta-Piceance Assessment Team, Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah, and Colorado, Chapter 7: U.S. Geological Survey Digital Data Series DDS-69-B, 63 p.

Schmoker, J.W., T.D. Fouch, and R.R. Charpentier, 1996, Gas in Uinta Basin, Utah—Resources in continuous accumulations: The Mountain Geologist, v. 33, no. 4, p. 95–104.

MODELING OF AN UNCONVENTIONAL GAS ACCUMULATION TAKING INTO ACCOUNT SPATIAL CORRELATION, GREATER NATURAL BUTTES, UTAH

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Background

- Unconventional (continuous) gas accumulations are reservoirs with a diffuse areal extent, no obvious gas-water contact, low permeability, close association with source rocks, that are difficult to assess volumetrically.
- Typical of the assessment of unconventional accumulations is the use of well estimated ultimate recovery (EUR) data as the main source of information. The other complementary and fundamental piece of information, the area drained by each well (support), is missing completely or highly incomplete.
- The importance of this type of accumulation is expected to grow, thus deserving enhancement of the existing resource assessment methods that for the most part do not take into account spatial correlation.

Presentation outline

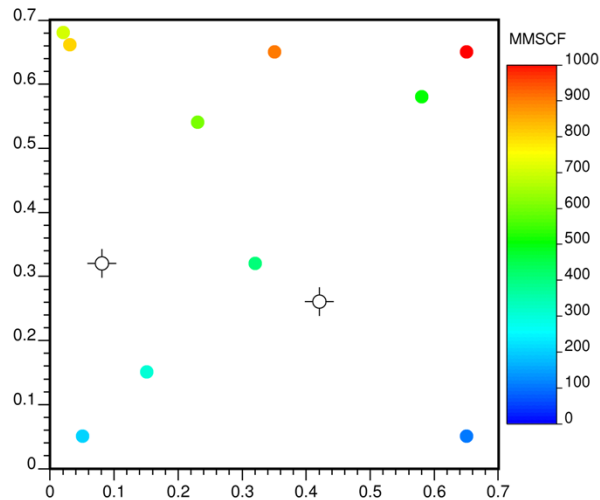
1. Methodology
2. Description of study area
3. Application of experimental methodology
4. Assessment of untested area
5. Conclusions

1. Methodology

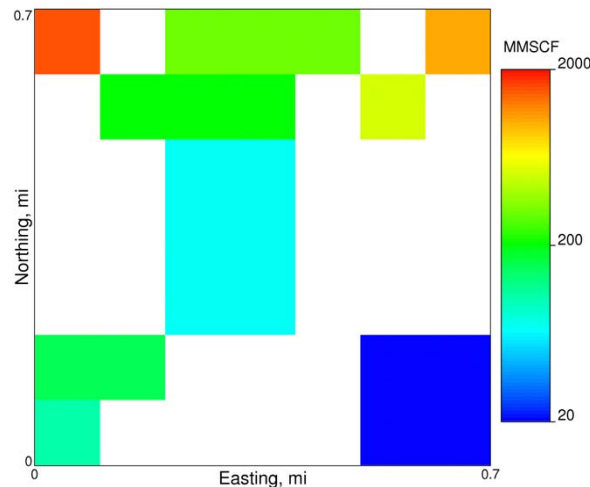
Modeling considerations

- Wells always drain a volume of rock, but the practice is to horizontally project such volume and work instead with a drainage area in map view.
- The attribute of interest is ultimate cumulative recovery (EUR), which typically is estimated from production curves.
- Correct modeling of EUR requires consideration of ultimate cumulative production relative to some uniform elemental area, here called “cell.”
- EUR per cell is equivalent to operating on the basis of an EUR density at a checkerboard.
- In a nutshell, this study deals with the mapping and assessment of EUR density considering spatial correlation.

Procedure (1)



Step 1

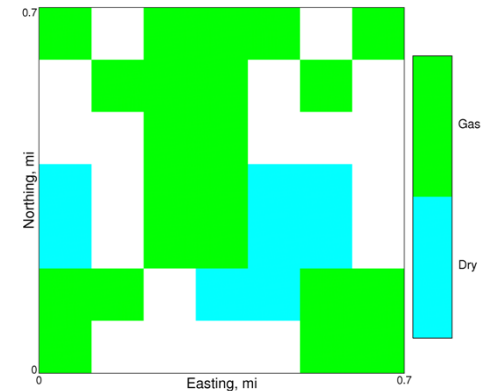


Step 5

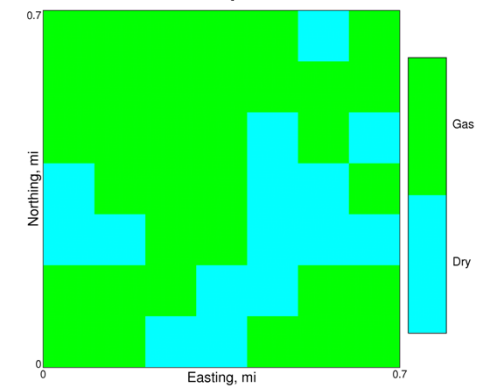
1. Display estimated ultimate recovery data (EUR).
2. Calculate the drainage area for all producing wells lacking such information.
3. Assign to each dry well a barren area equal to the drainage area of the closest producer.
4. Subdivide the study area into square cells with an area equal to the minimum drainage area.
5. Convert well EURs into EURs per cell to have the data as EUR density.

Procedure (2)

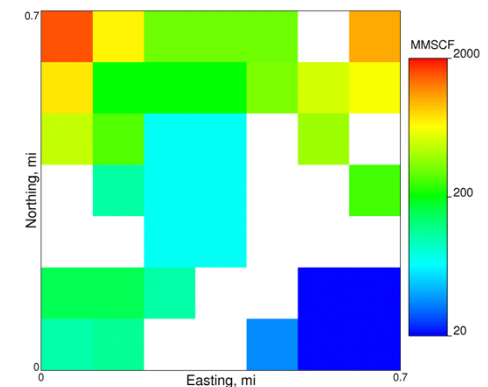
5. If necessary, use the standard error map prepared with indicator kriging to limit extrapolations in areas without sufficient data.
6. Define a production indicator for all cells drained by the wells.
7. Apply sequential indicator simulation to generate equiprobable maps for the extension of the entire accumulation.
8. Use simulation to generate as many cell EUR maps as boundary maps.
9. Prepare the assessment.



Step 6



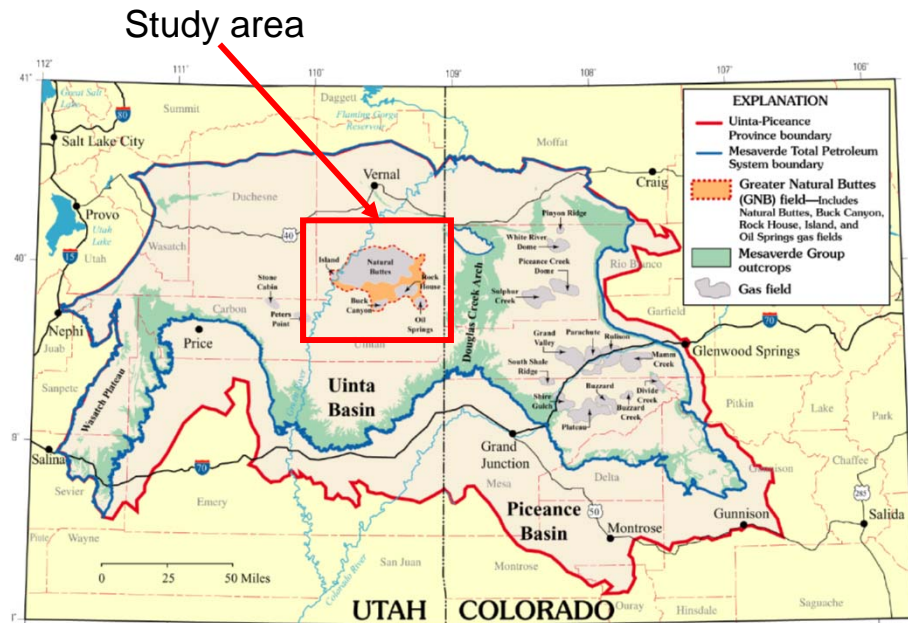
Step 7



Step 8

2. Description of study area

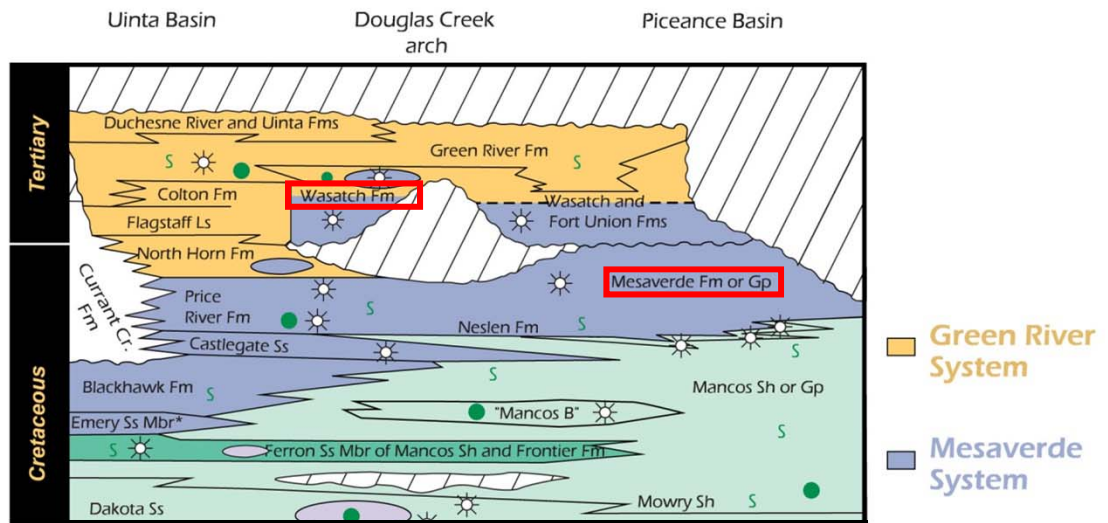
Greater Natural Buttes



Modified from Johnson and Roberts (2003)

- Areal extension is approximately 500 sq mi.
- There were 2,488 producers and 1,146 dry wells by 2007.
- Production is from lenticular sandstones.

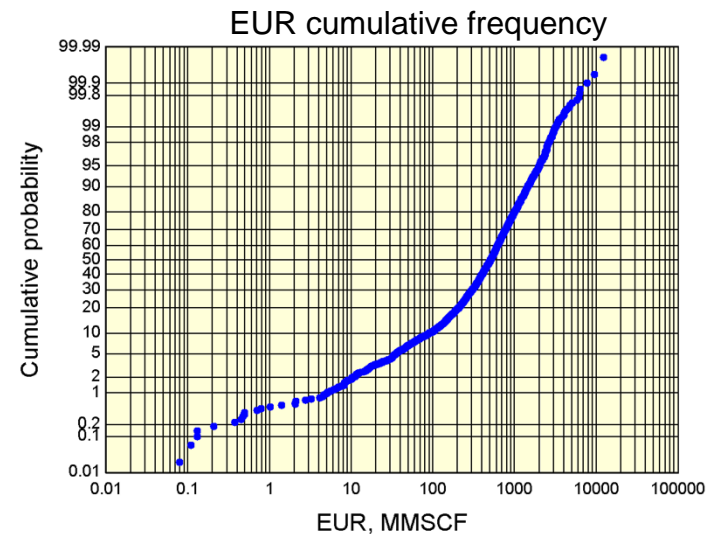
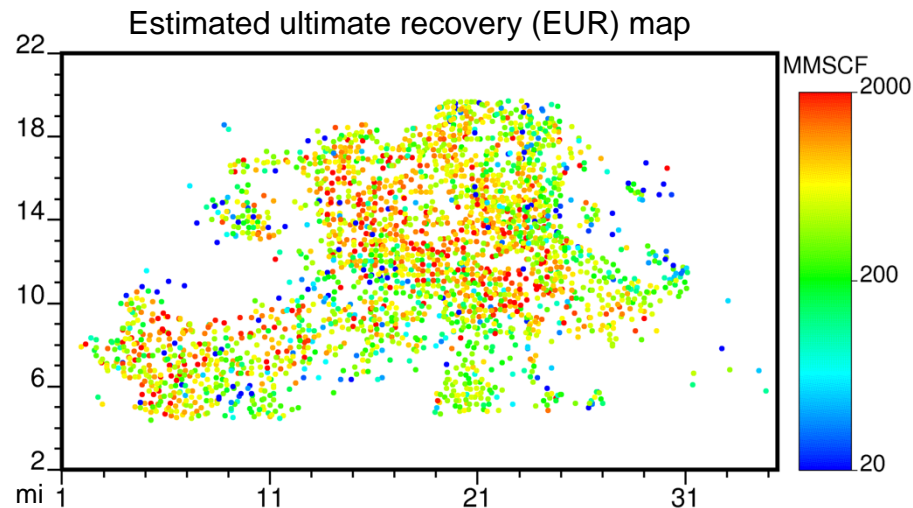
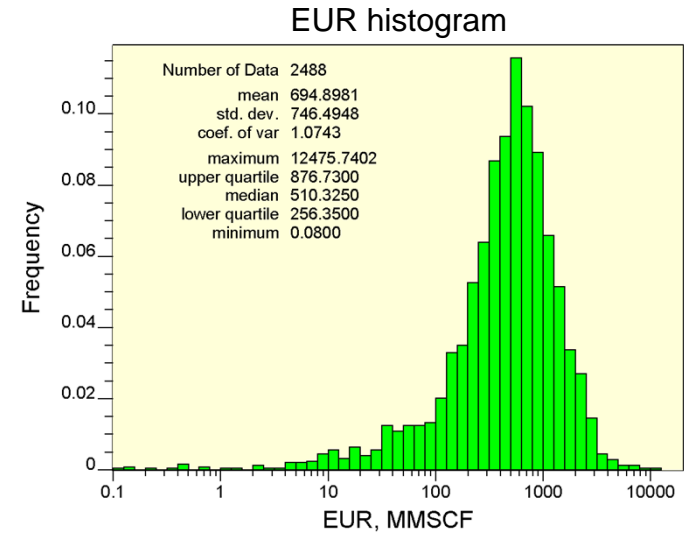
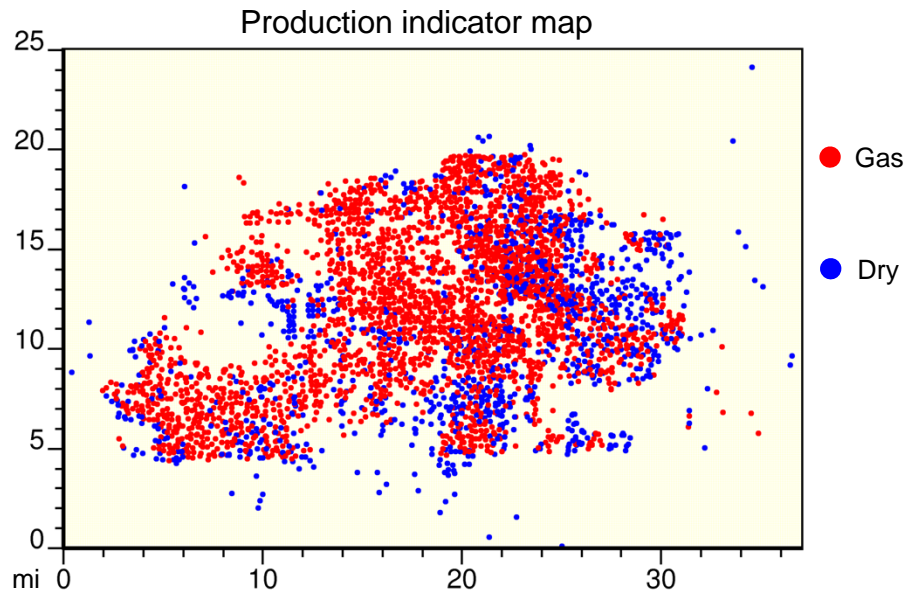
Cumulative production of existing wells is supposed to account for 1.7 TSCF.



Modified from Johnson and Roberts (2003)

3. Application of experimental methodology

Location and actual well production data

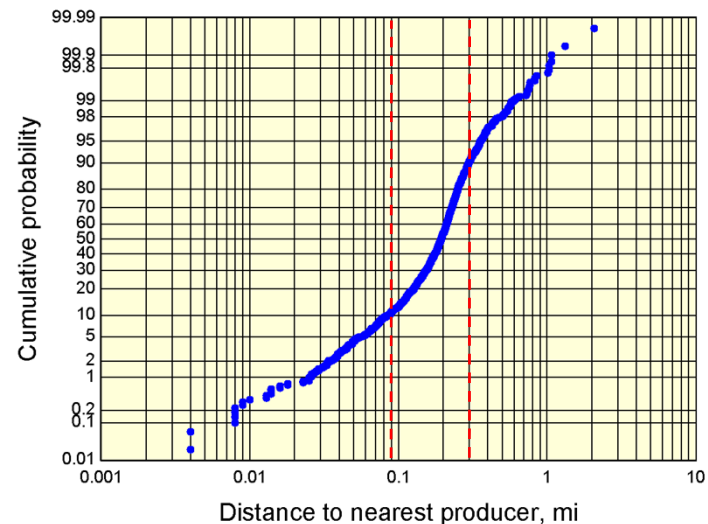
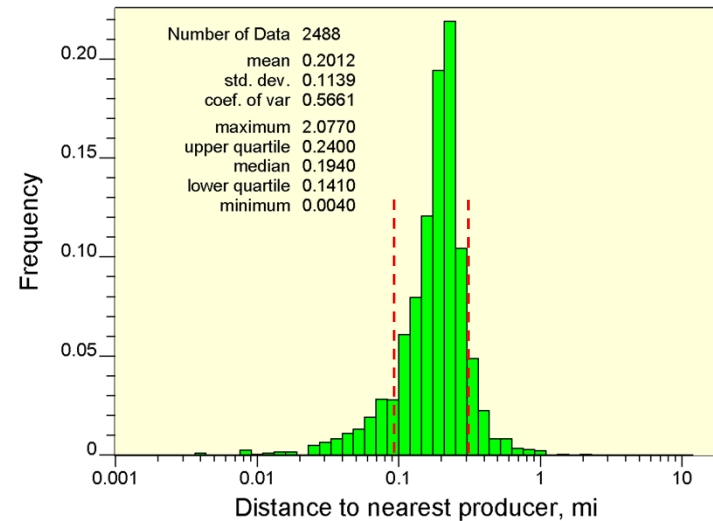


Calculation of drainage area

There are no values available for drainage area.

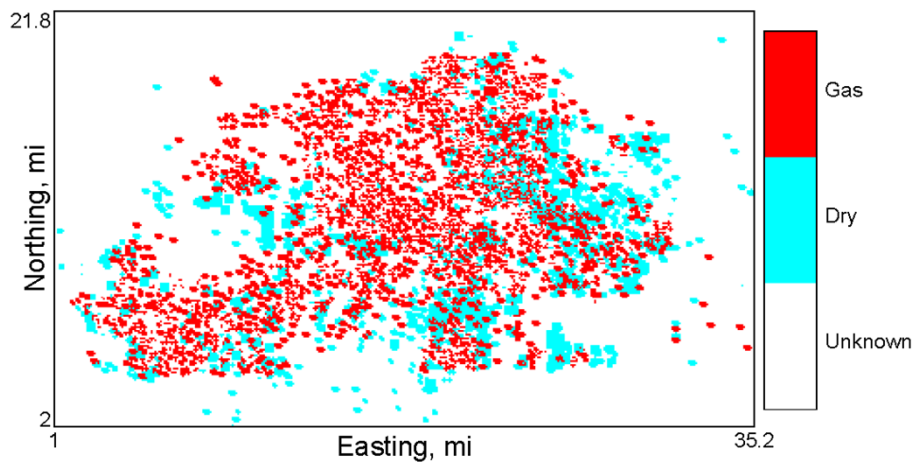
Because the area is mature, the radius of the drainage area was set equal to half the distance to the closest producer, with a lower limit of 0.09 mi. and an upper limit of 0.31 mi.

The barren area around a dry well was made equal to the drainage area of the closest producer.

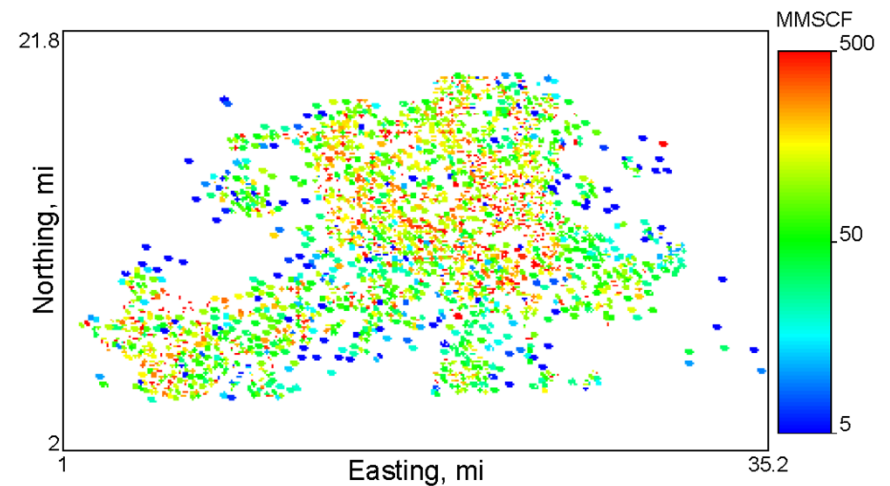


Data after homogenization of cell support

Known extension of accumulation

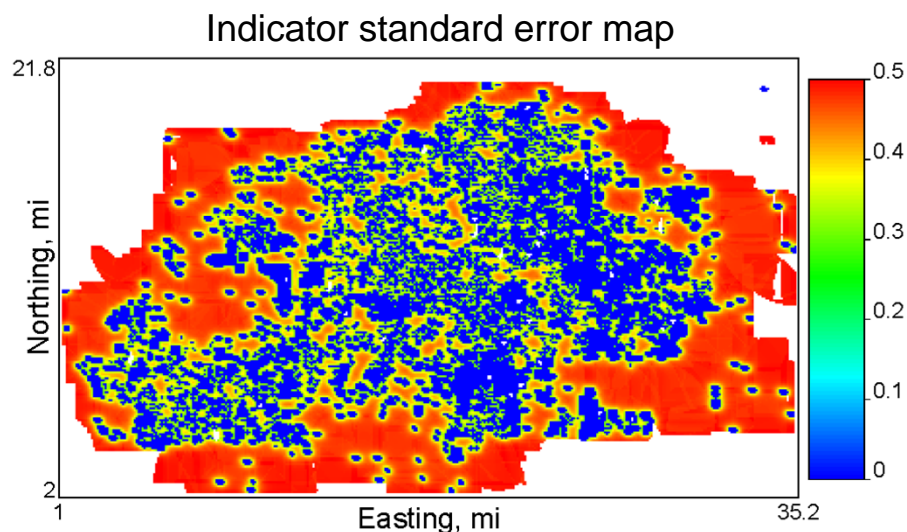


Cell productivity at 5 ac cells



Well drainage was modeled with preferential direction along fractures reported approximately along S80E.

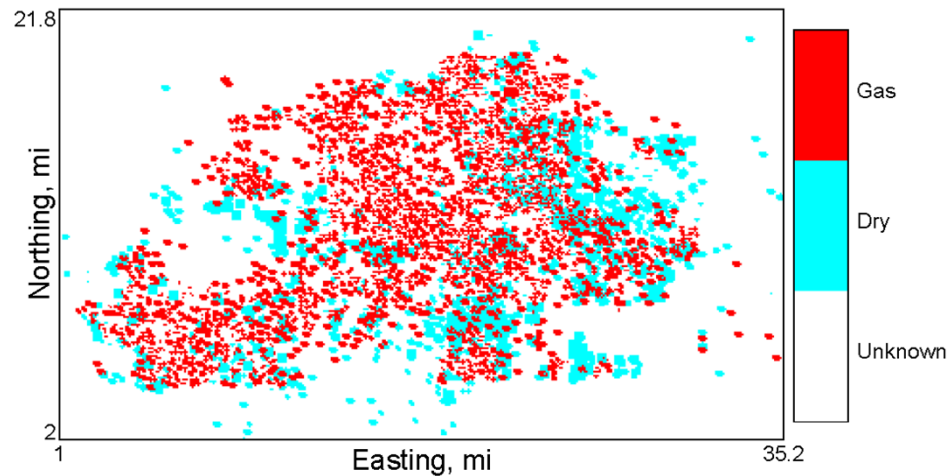
Study area



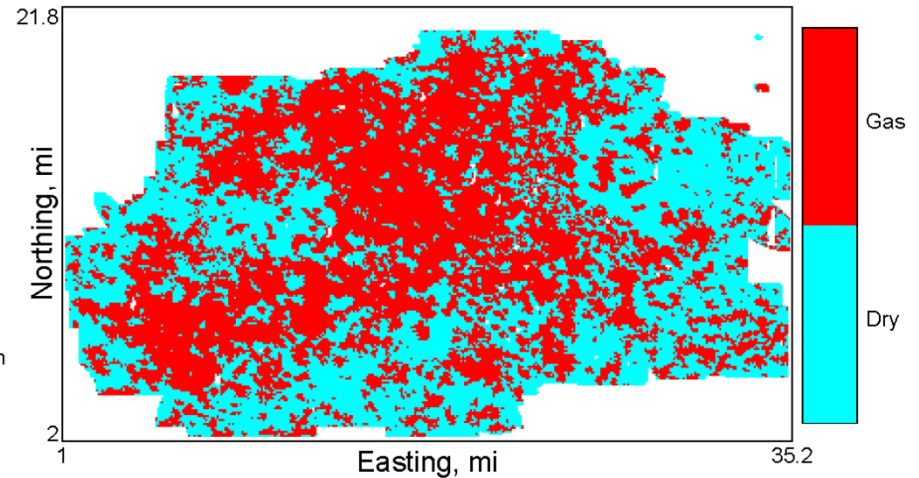
According to kriging of production indicators, the extension of the area amenable to assessment is the colored area above, which accounts for 490 sq mi.

Equiprobabilistic views of the accumulation

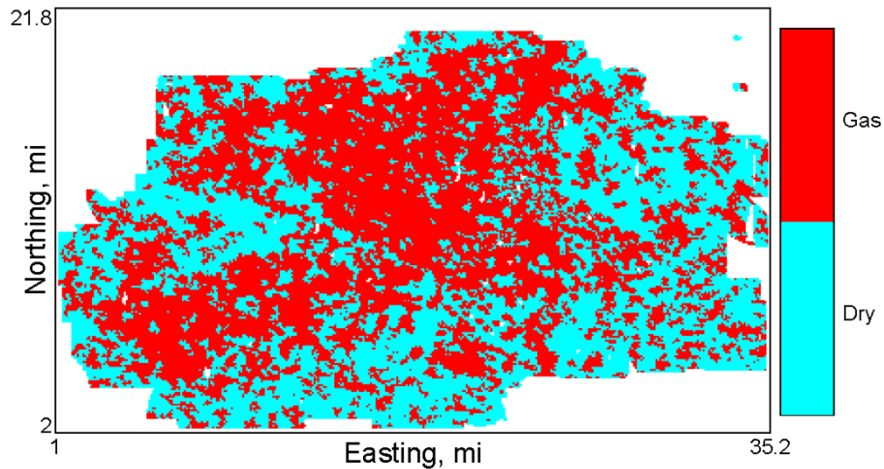
Indicator data



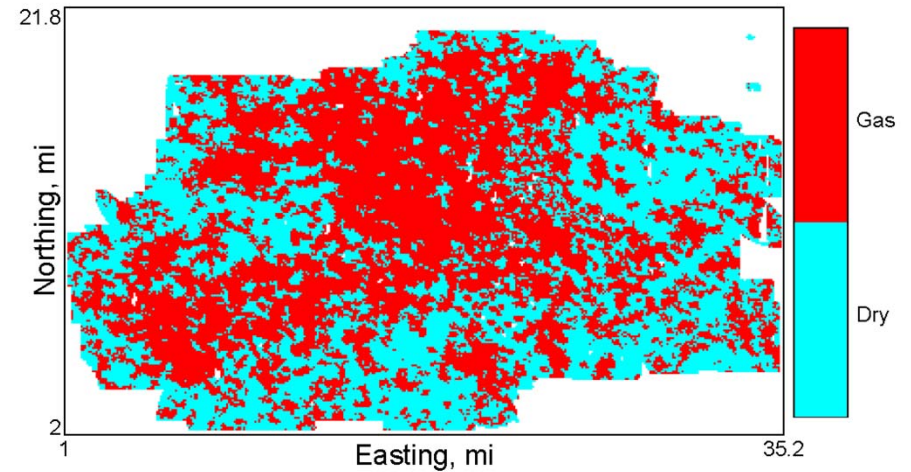
Minimum producing area



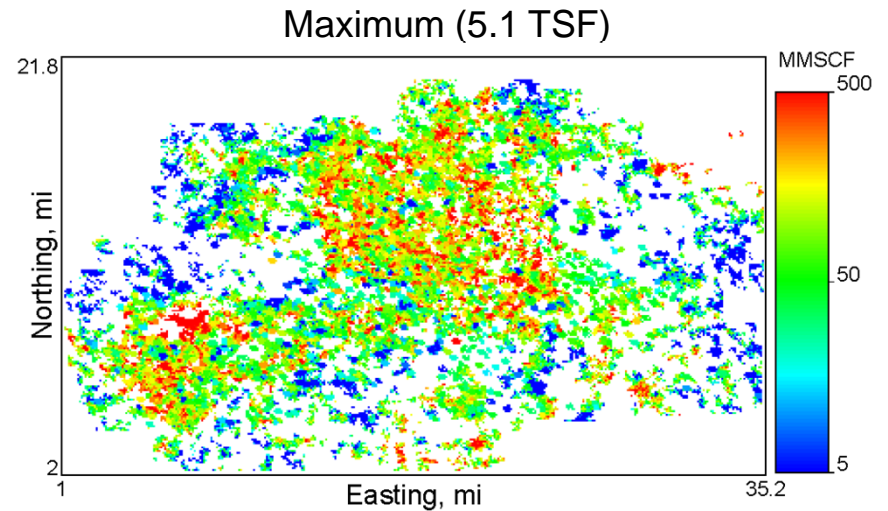
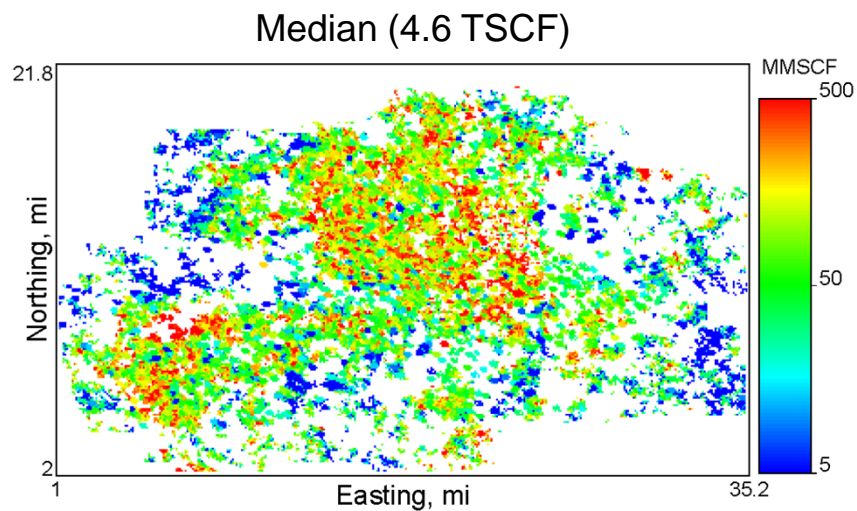
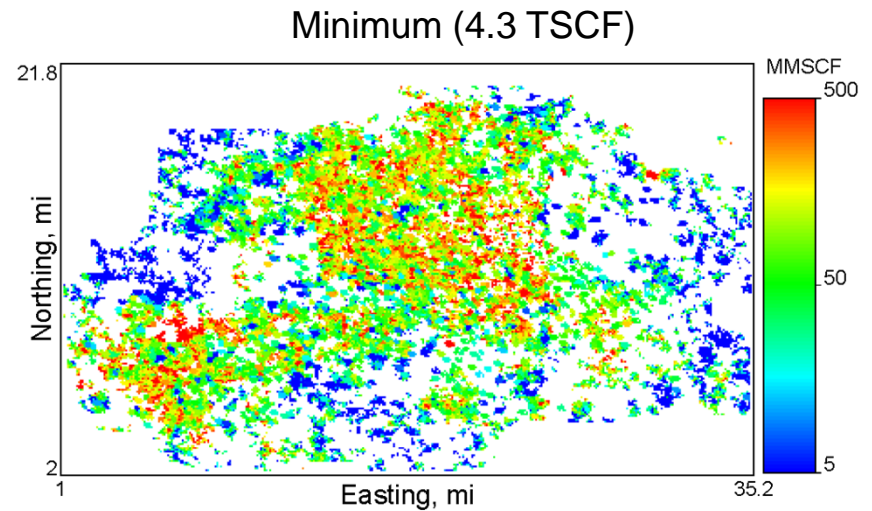
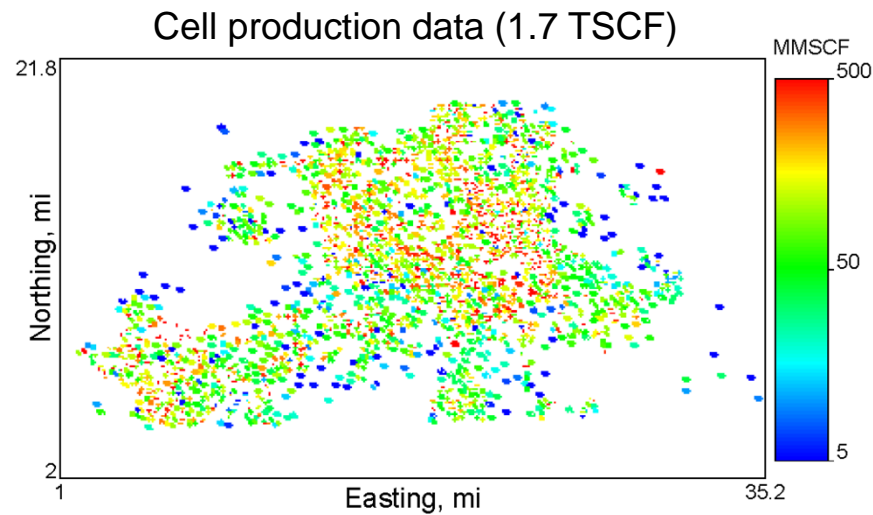
Median producing area



Maximum producing area

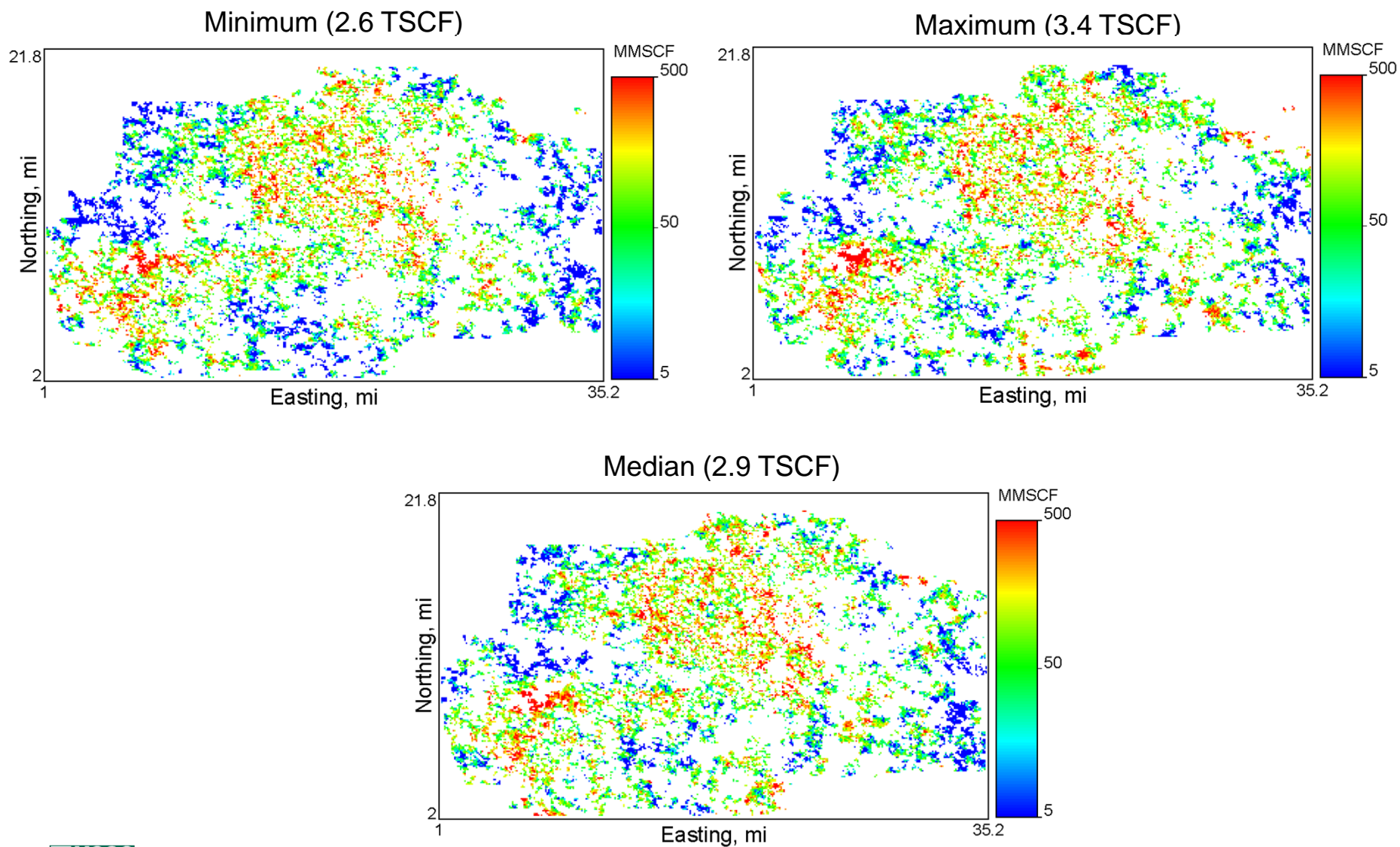


Inference of cell production

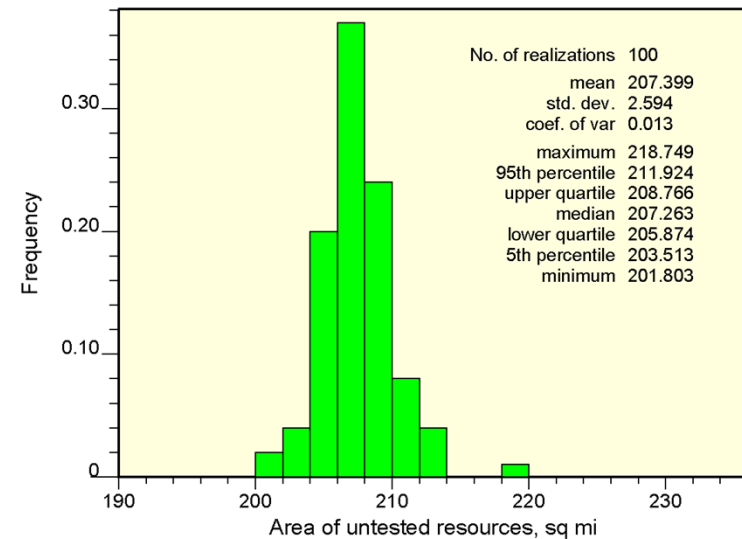
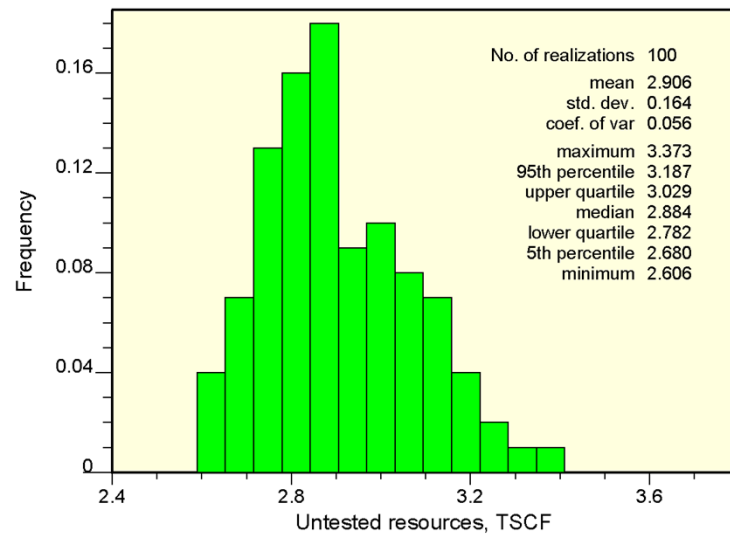
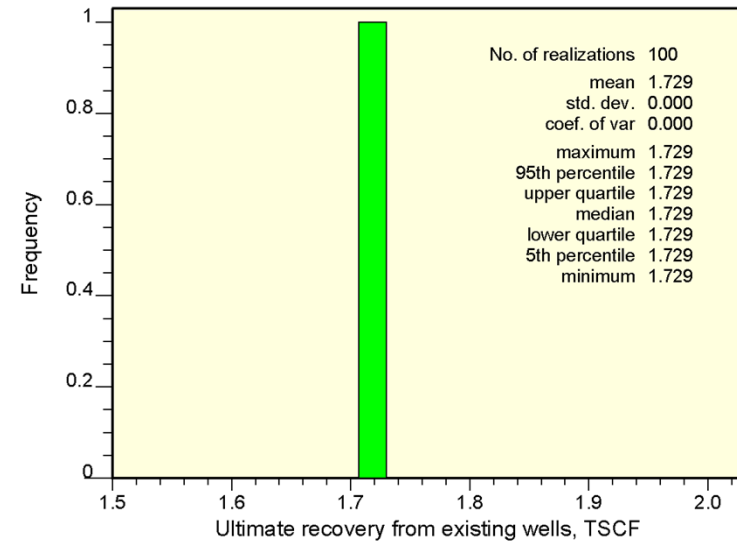
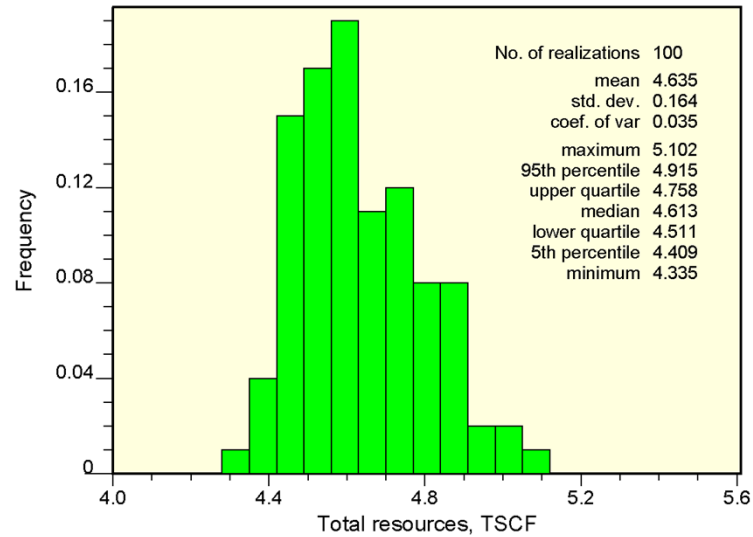


Realizations generated with sequential Gaussian simulation

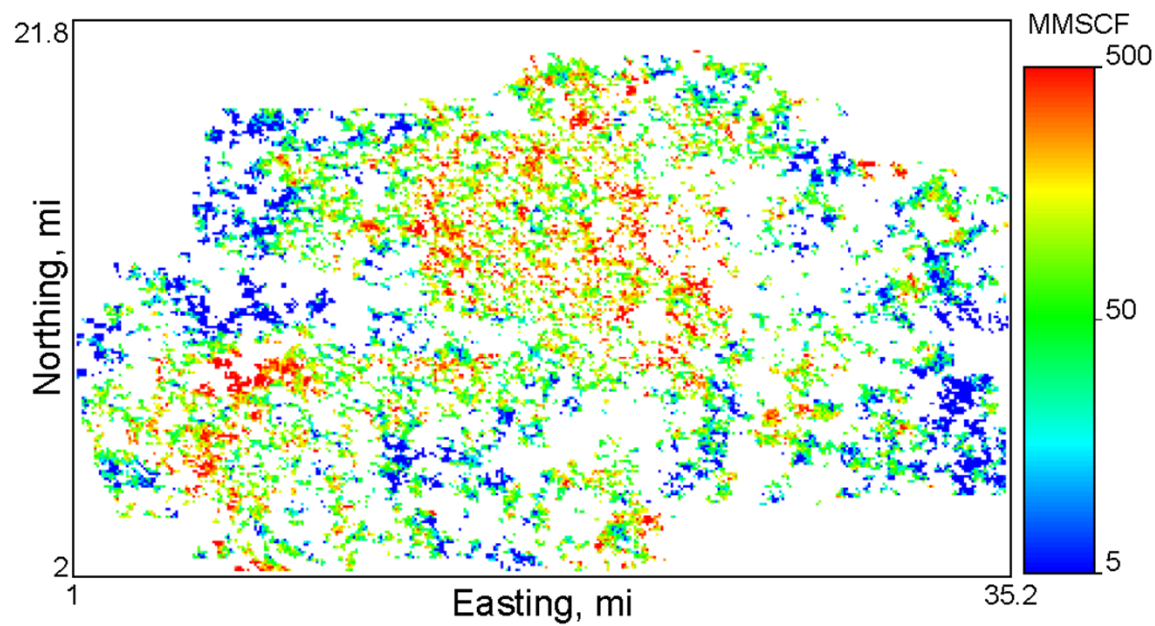
Resources at cells not drained by existing wells



Stochastic quantification of resources

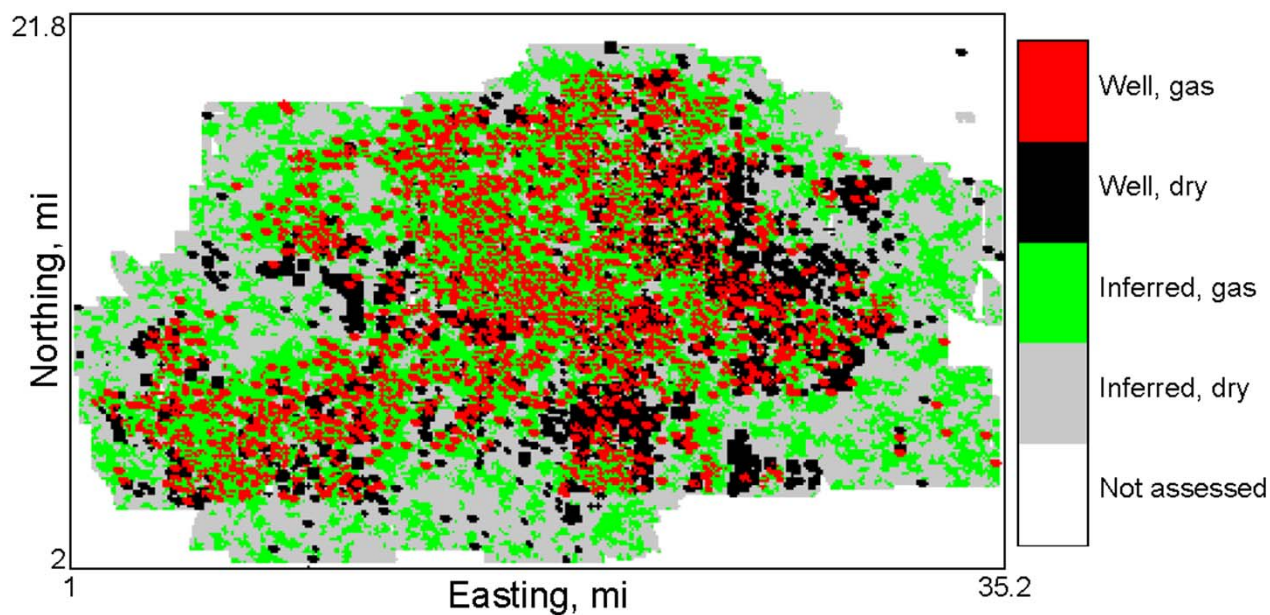


Median untested resources



Mapping of production modeling

Resource classification of median scenario above



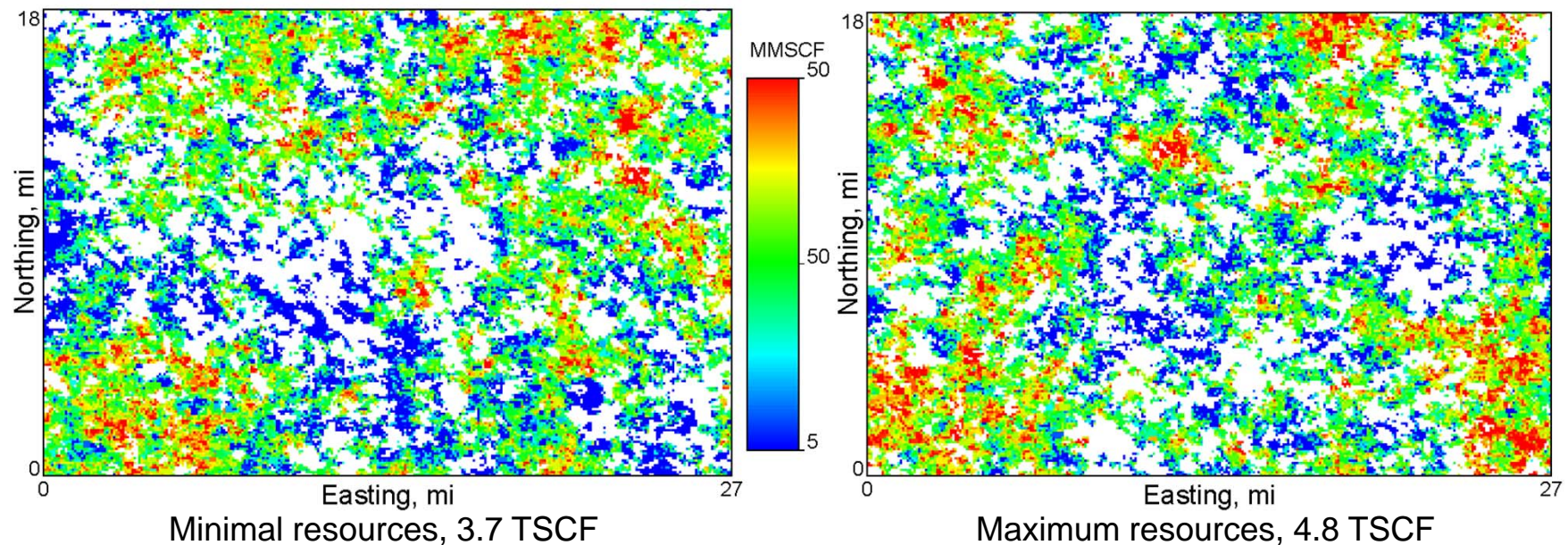
4. Assessment of undrilled area

Assessment of area not yet drilled

Application of multiple point simulation allows assessment of area without EUR data.

It is necessary to select as training image the EUR map of an area regarded geologically analogous.

EUR realizations based on the Greater Natural Buttes median realization



Conclusions

- Breaking of drainage area into cells of homogenous shape and size allows EUR mapping as well as modeling of uncertainty in resource assessment, both following the style of spatial variation in the data.
- EUR maps are adequate for economic evaluations.
- Geology can be made part of the methodology if quantitative data are available. In this study, we biased drainage along the direction of a reported system of fractures.
- Our modeling of total resources (F5: 4.4 TSCF; F95: 4.9 TSCF) is in the upper tail of the total resources modeled 15 years ago based on about one third of the wells (F5: 1.4 TSCF; F95: 5.4 TSCF) (Schmoker 1995).

Winter drilling at Greater Natural Buttes



Photo by: David Tejada, 2008