Fitting Variograms to Hugoton/Panoma Facies and Porosity Data

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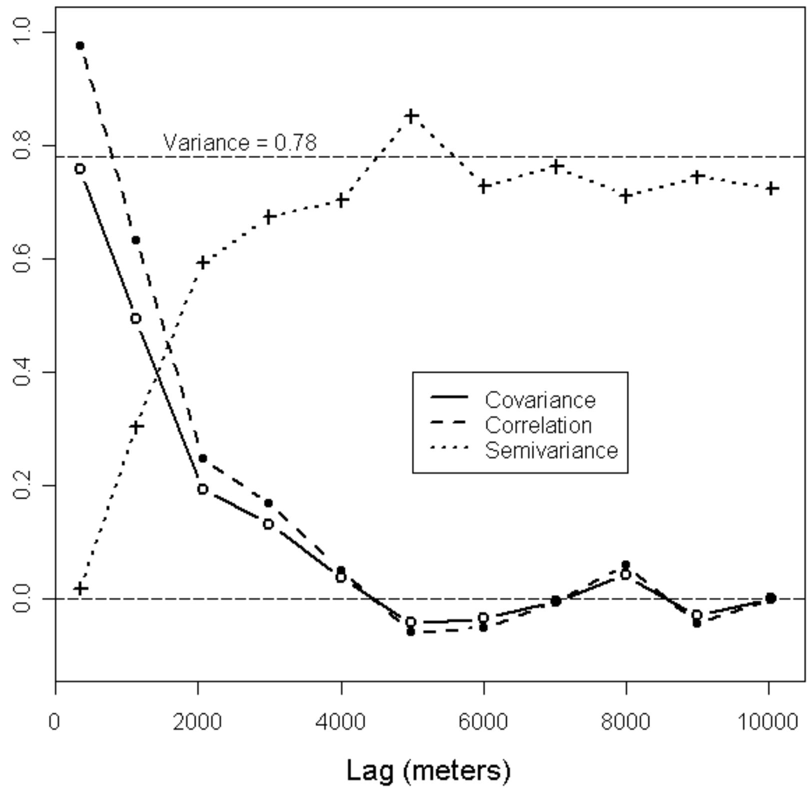
What’s a (Semi)variogram

- Average squared difference between observed values as a function of separation or “lag” distance between the observations
- Closer observations are generally more alike than more distant observations, so semivariogram generally increases with lag
- Semivariogram is sort of an upside version of the spatial autocorrelation function

Example Semivariogram



Raw (unscaled) semivariogram for some porosity data with a global variance of 0.78.

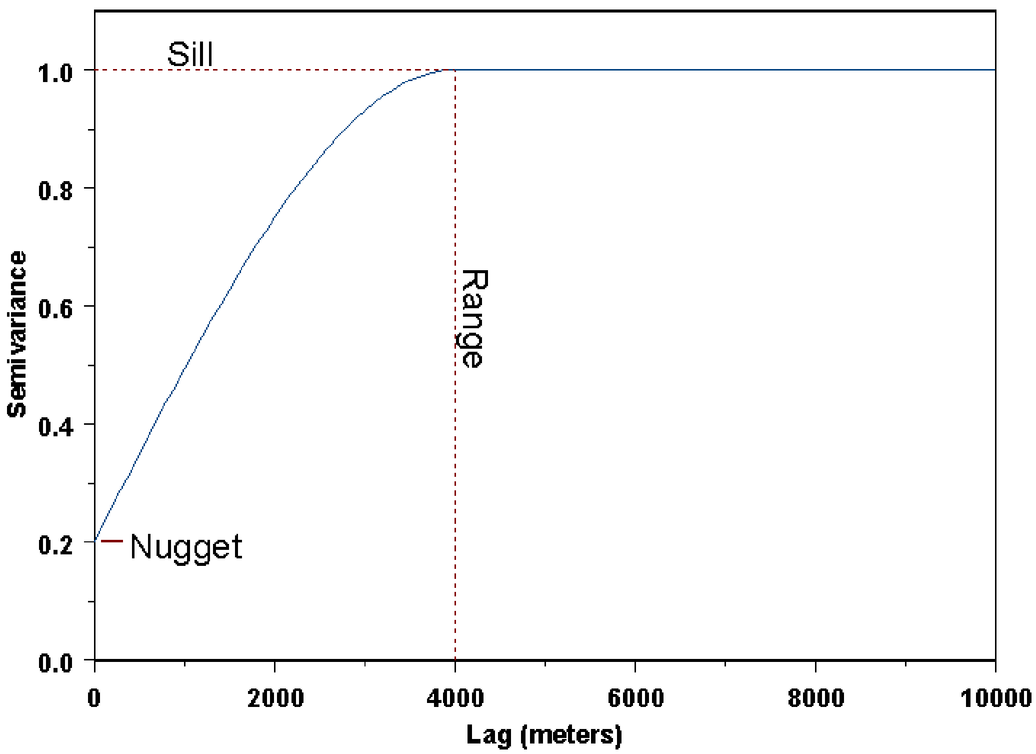
Why Do We Need a Semivariogram?

- Serves as the basis for computing interpolation weights in kriging
- Kriging is “optimal” interpolation, in the least-squares sense
- Kriging also underlies stochastic simulation algorithms used to model facies and porosity

Why Do We Need a Semivariogram Model?

- Need semivariogram values for lags other than those in empirical semivariogram
- Kriging equations will break down if we try to use arbitrary semivariogram values
- Conventional ("licit") models are designed to keep the kriging equations happy

Semivariogram Characteristics

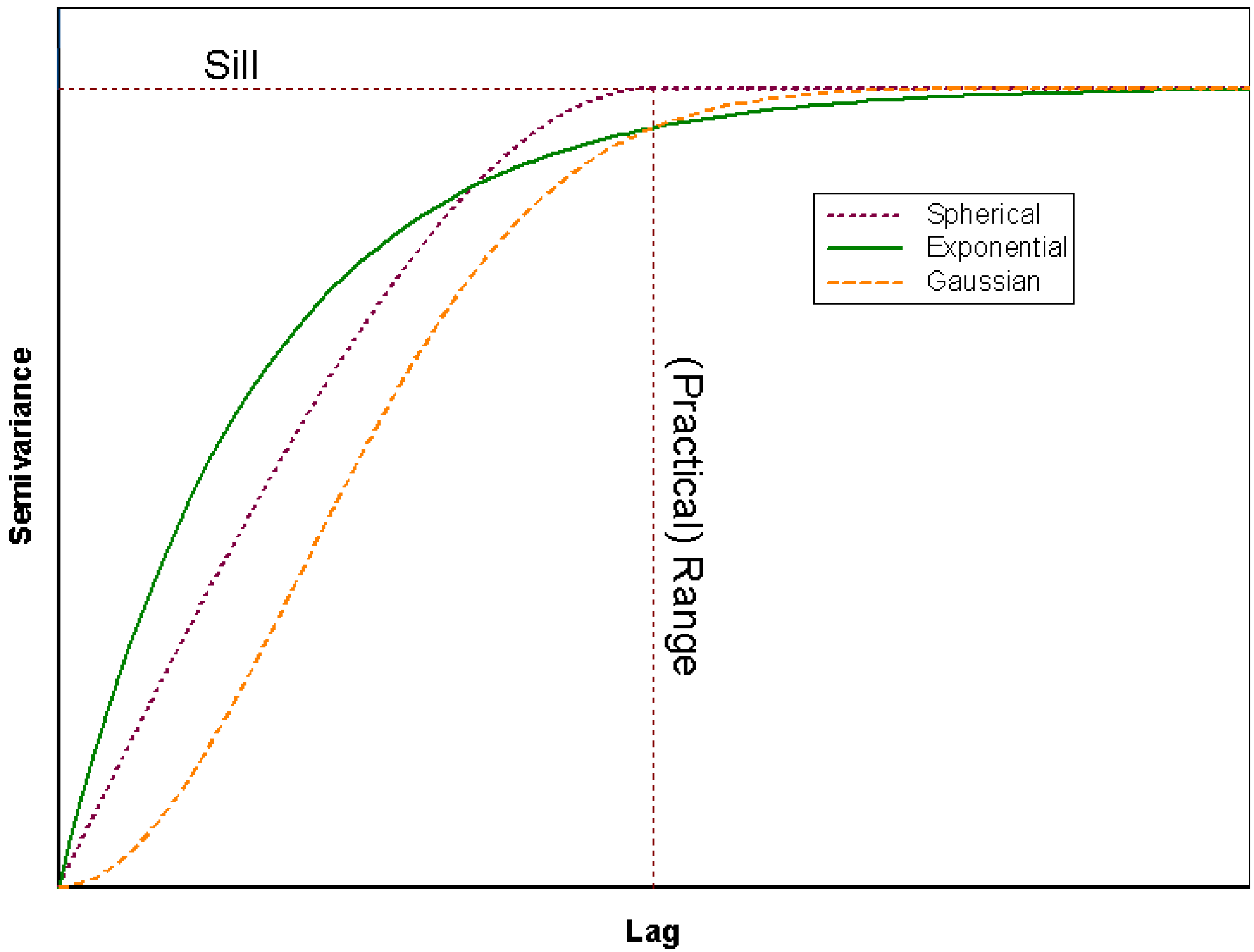


Sill: Semivariance at which semivariogram levels off; *should* equal global variance

Range: Distance at which semivariogram reaches sill; observations separated by distances greater than range are uncorrelated

Nugget: Represents variability at short distances (e.g., smaller than typical well spacing); high nugget implies noisy property

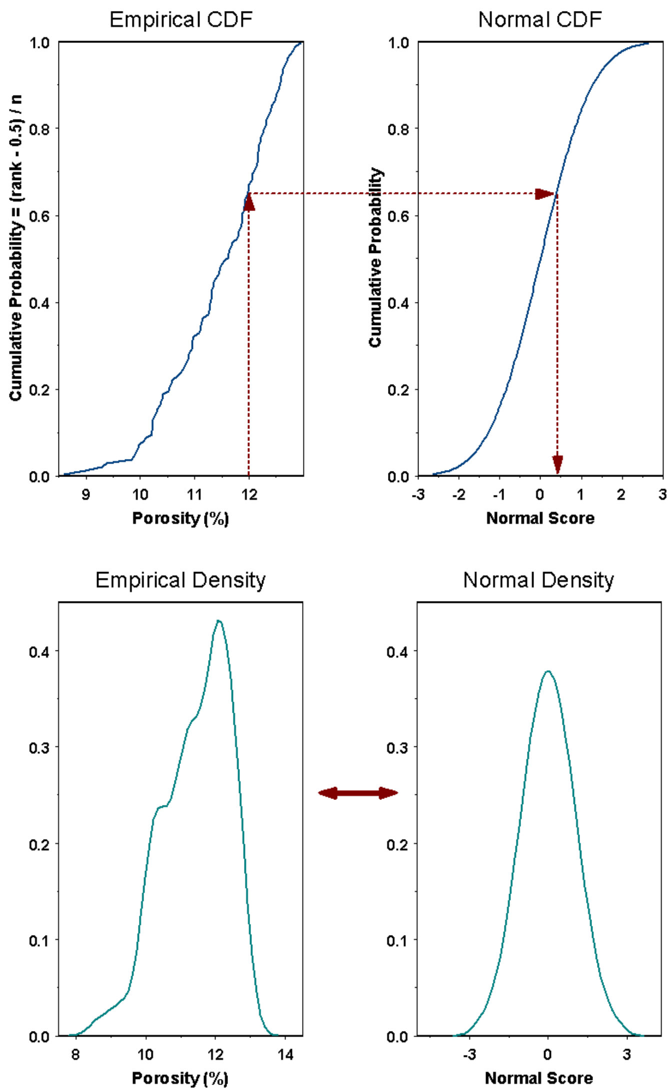
Standard Semivariogram Models



Normal Score Transform

- Kriging/Simulation optimal for normally distributed data
- Normal score transform applied to continuous variable like porosity
- Replaces original data with data following perfect standard normal distribution
- Variance of transformed data is 1; sill of semivariogram should also be 1
- Backtransform to original variable after simulation

Normal Score Transform



- Kriging/Simulation optimal for normally distributed data
- Normal score transform applied to continuous variable like porosity
- Replaces original data with data following perfect standard normal distribution
- Variance of transformed data is 1; sill of semivariogram should also be 1

Scaling by p*(1-p)

- For categorical (binary) data like facies occurrence
- Overall variance of binary variable should be p*(1-p), where p is the probability of occurrence – a.k.a., volumetric proportion of facies
- Scaling semivariogram by p*(1-p) *should* yield sill of 1

Sequential Gaussian Simulation (porosity)

- Generate a random path through the grid nodes
- Visit the first node along the path and use kriging to estimate a mean and standard deviation for the variable at that node based on surrounding data values
- Select a value at random from the corresponding normal distribution and set the variable value at that node to that number
- Visit each successive node in the random path and repeat the process, including previously simulated nodes as data values in the kriging process

Sequential Indicator Simulation (facies)

- Generate a random path through the grid nodes
- Visit the first node along the path and use indicator kriging to estimate occurrence probability for each facies
- Generate a uniform random number and use this to sample from facies cumulative density function (built from occurrence probabilities)
- Visit each successive node in the random path and repeat the process, including previously simulated nodes as data values in the kriging process

More Background

- Geostatistics lectures available at http://people.ku.edu/~gbohling/cpe940
- *Geostatistical Reservoir Modeling* by Clayton V. Deutsch, Oxford University Press, 2002.

Hugoton/Panoma Variogram Estimation

- 11 facies x 24 zones x 3 directions x 2 properties (facies, porosity) = 1584 possible semivariograms!
- To reduce the burden, look at each submodel lumped (all zones together) and only two directions: horizontal (omnidirectional) and vertical
- 11 facies x 6 models x 2 directions x 2 properties = 264 possible semivariograms

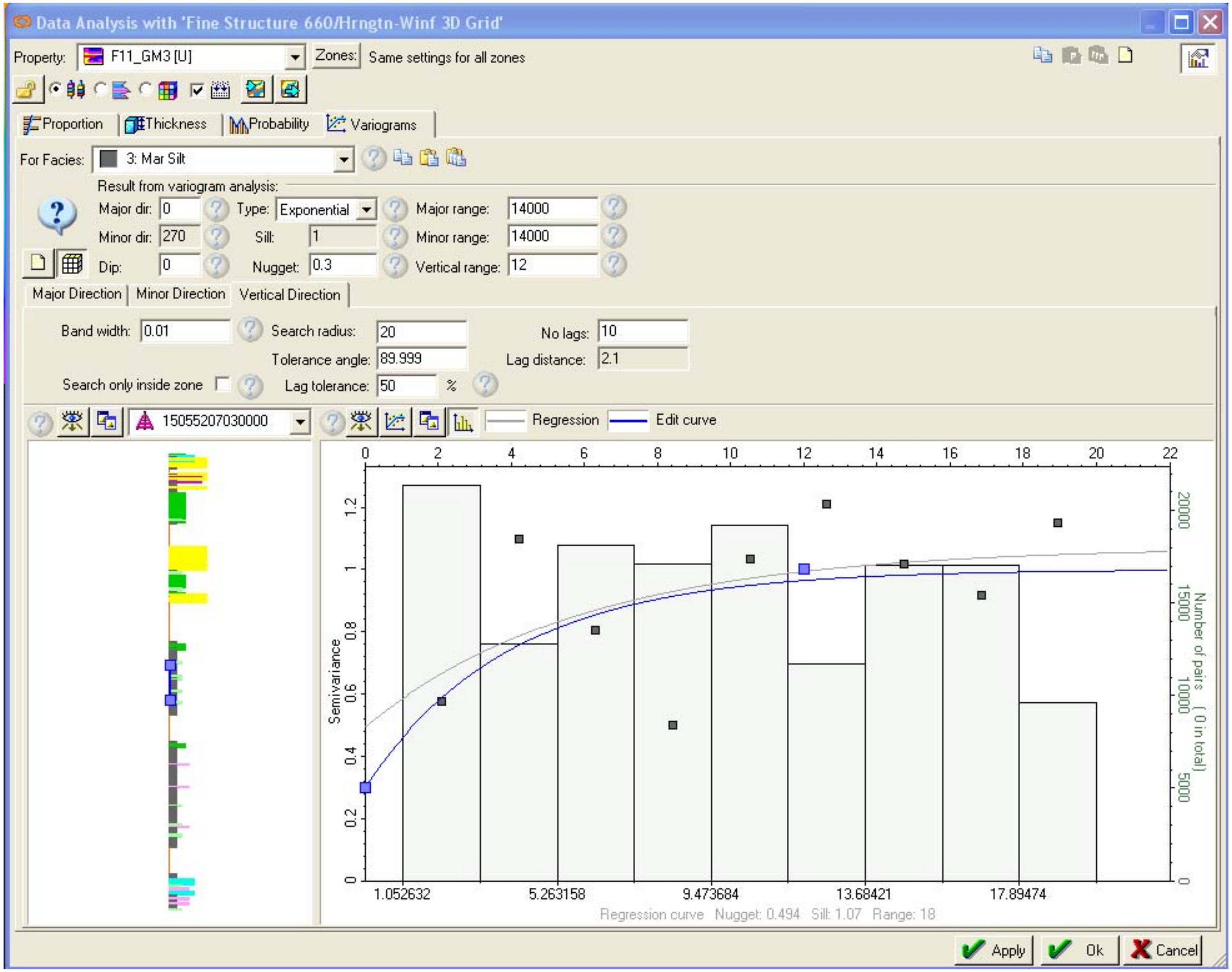
Trying It In Petrel

- Overall result: Immense frustration
- Far too much time spent watching the hourglass while Petrel cranks through data to produce very badly behaved semivariograms
- Too much tweaking, compromising needed to fit ugly variograms going at snail's pace in Petrel

Typical Bad Behavior

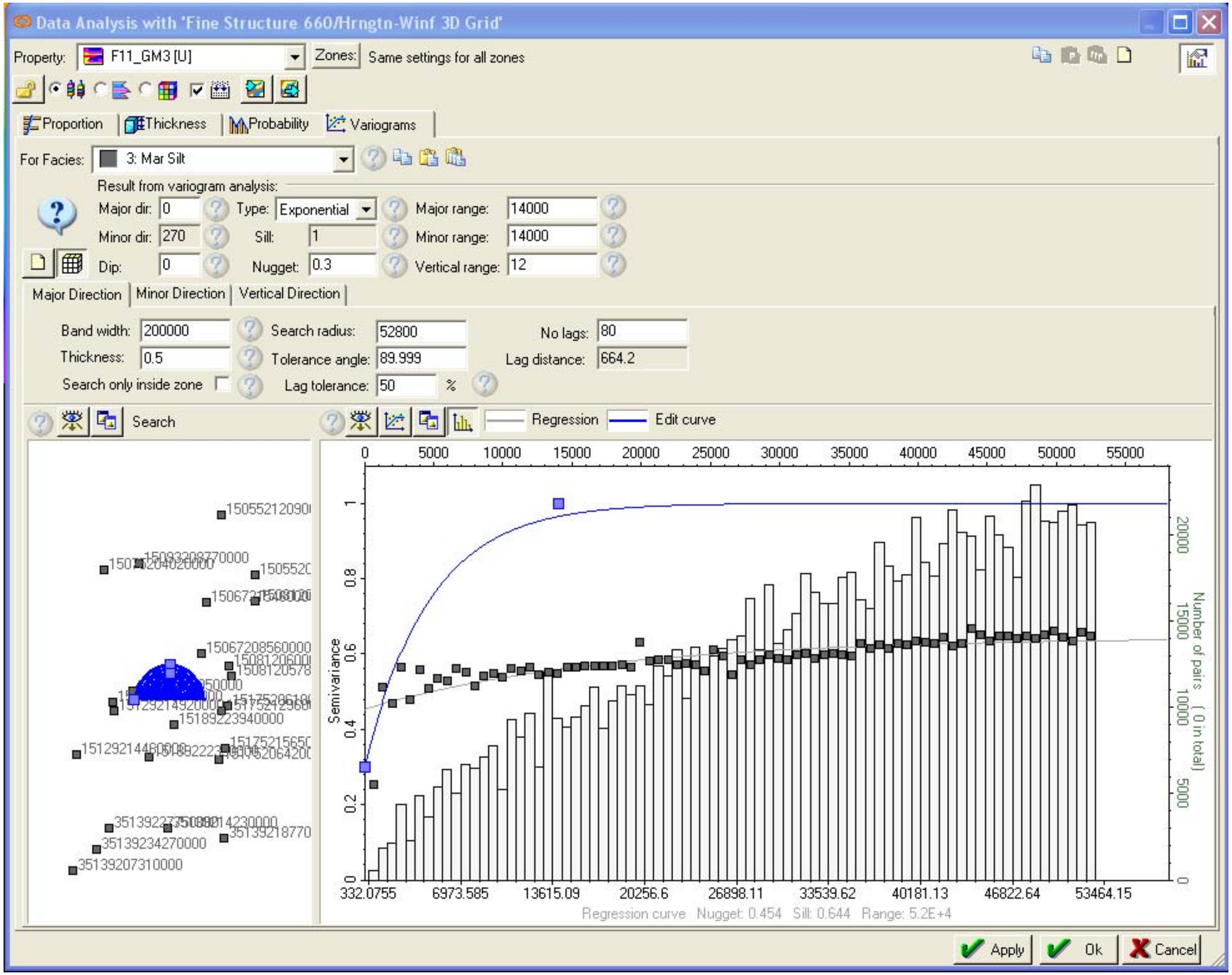
- Sills significantly less than 1 for both facies and porosity in horizontal direction
  - Probably due in part to zonal anisotropy: not seeing full range of variability looking in horizontal direction
- High nuggets: Lots of short-scale variability; would result in noisy simulations
- Very ratty vertical semivariograms

An Example Vertical Semivariogram



Not nearly as bad as some

An Example Horizontal Semivariogram



Pretty typical; actual sill nowhere near *enforced* model sill of 1

To Deal With It All…

- Exported upscaled facies and porosity to GSLIB-format ASCII files (one for each submodel)
- Read data into R and did variogram computation and fitting using R scripts; employing *gstat* library for R
- Does *not* eliminate bad behavior; just allows more efficient data handling

Exporting Upscaled Data

- Filter model only on well cells
- Use calculator to compute copies of facies and porosity with filter on
- Export those copies to GSLIB grid, excluding missing values (vast majority of grid cells) from export

Computing Empirical Semivariograms

- Horizontal lags: 660-foot nominal lag spacing out to 52800 feet (10 miles, 80 lags)
- Vertical lags: 2-foot nominal lag spacing out to 40 feet (20 lags)
- For horizontal vg’s: p*(1-p) or normal-score scaling applied on a layer-by-layer basis then scaled variograms averaged over layers to try to reduce effect of zonal anisotropy; helped *some*

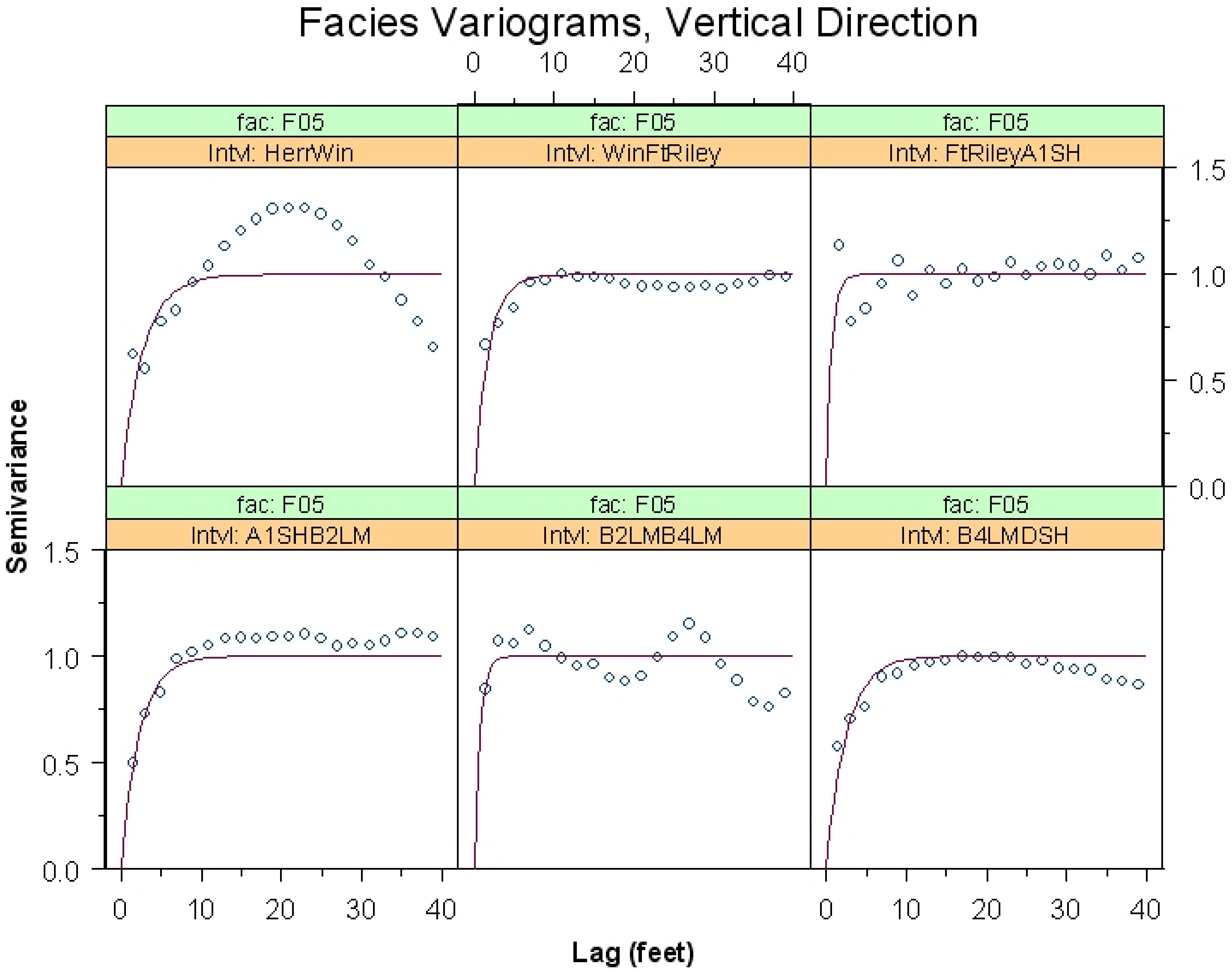
Vertical Distances

- Reasonable to look at fairly large vertical distances (up to 40 feet) for facies
  - Need to look over a few cycles to get reasonable estimate of vertical extents (ranges)
- A little more iffy for porosity – larger lags include porosity values from facies bodies in different zones
  - But need broader sample to get decent vg

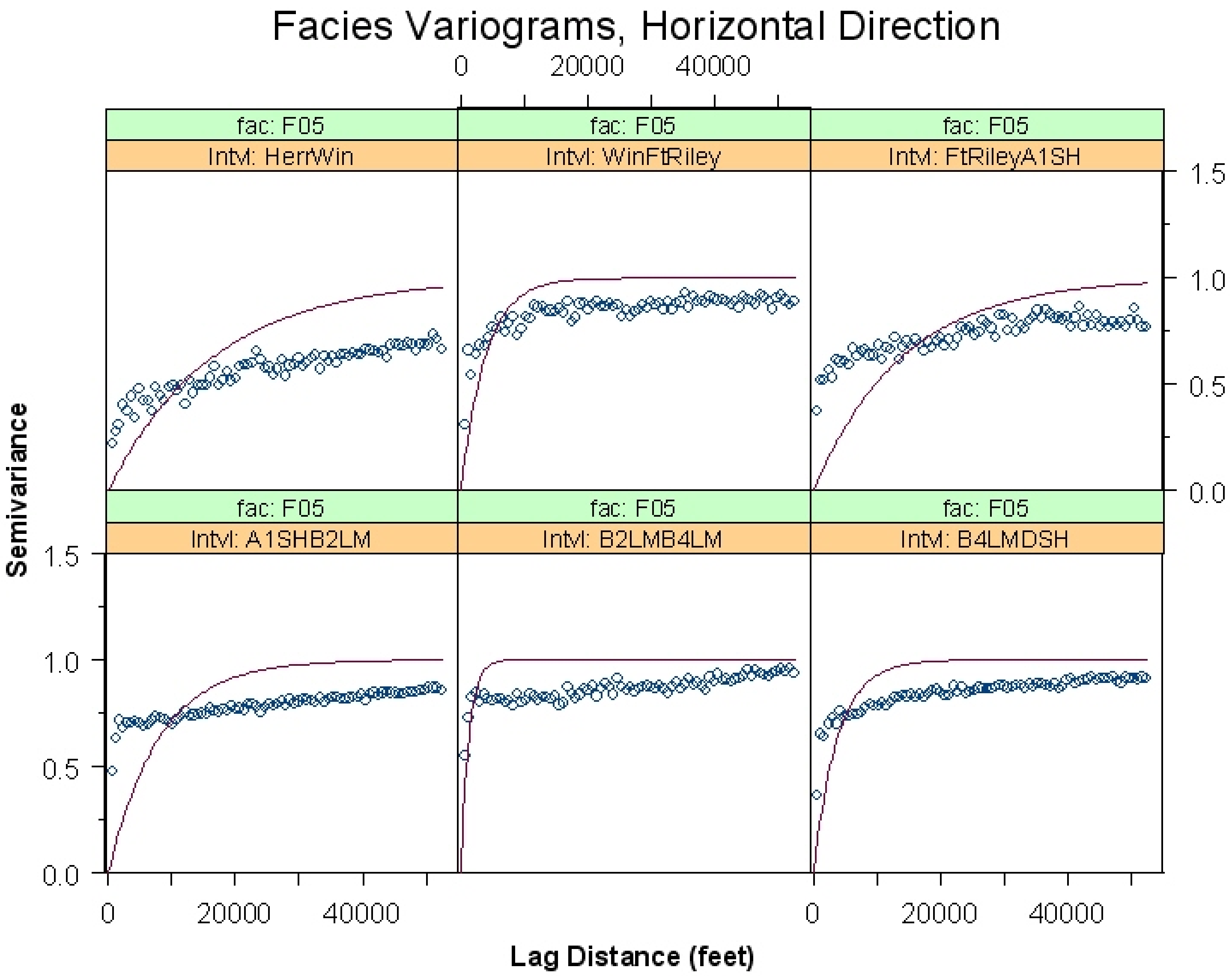
Model Fitting

- By fiat: Exponential models with zero nugget (to be checked after the fact)
- Omnidirectional horizontal model (no horizontal anisotropy)
- Reduces problem to estimating horizontal and vertical ranges
- Only compute vg & estimate model if facies proportion is at least 10%
- Maximum allowed ranges: 50000 feet horiztonal, 25 feet vertical

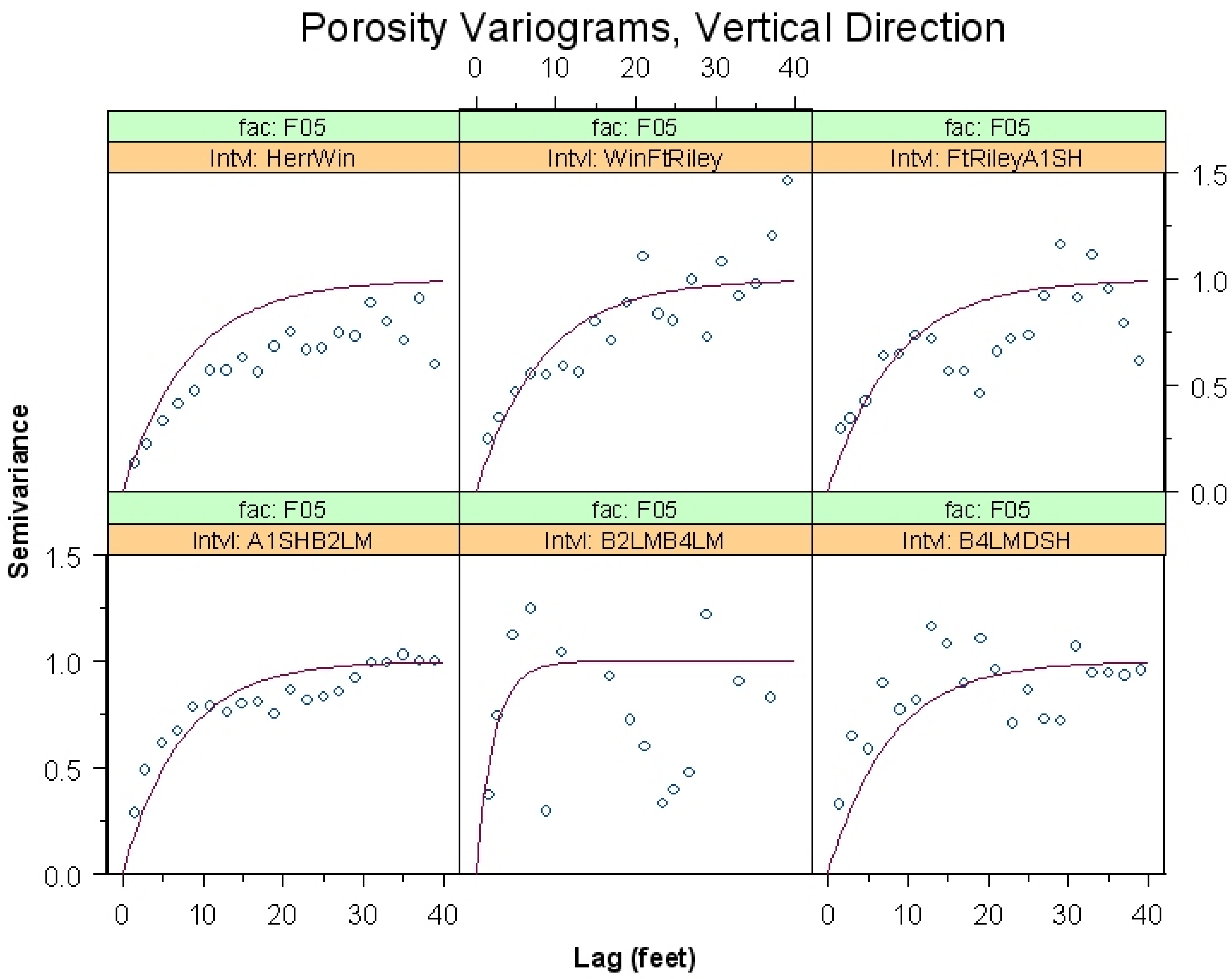
Example Vertical Facies Semivariograms



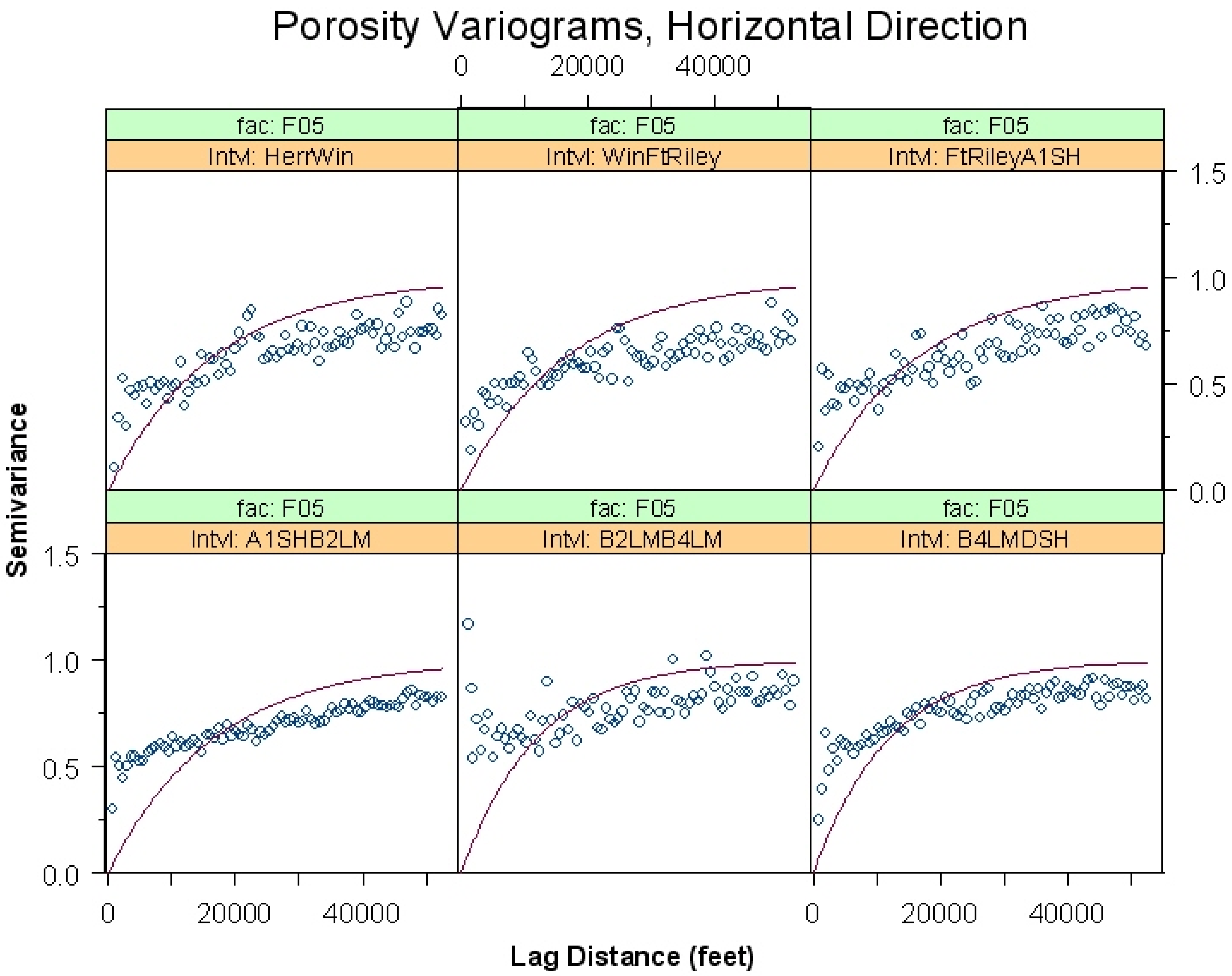
Example Horizontal Facies Semivariograms



Example Vertical Porosity Semivariograms



Example Horizontal Porosity Semivariograms



General Results

- Vertical facies variograms pretty decent
  - In general justify zero-nugget exponential models
- Horizontal facies variograms still badly behaved
  - Short-range models emulating pure nugget
  - Fitted range at 50000 upper limit for many vg’s that do not reach sill of 1
  - A few decent fits with horizontal ranges of 18,000 to 30,000 feet
- Porosity semivariograms kinda the same but generally rattier
- Geoff graded the fits (good, so-so, meaningless) and passed those results on to Marty

Variograms used in Geomod4

Methodology:

1. Analyzed variogram parameters from analysis
2. Where there was sufficient data, calculated mean values by facies by group (Chase and Council Grove) and combined (Wolfcamp). Ranges of 50,000 were not considered.
3. Used mean ranges by group (Chase or Council Grove) where there was sufficient data, otherwise used combined mean (Wolfcamp)
4. Modified in special cases to attain reasonable facies distribution patterns in the model

Chase Group – Lithofacies variograms

General Rules:

1. Horizontal major axes are average for either the Chase or Wolfcamp (Chase & Council Grove)
2. For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.
3. Azimuth is 11 degrees, same as in Geomod3. This is approximate regional strike.
4. Vertical ranges are average for either the Chase or Wolfcamp (Chase & Council Grove).
5. Used shorter vertical ranges for facies that are out of place for the zone
6. Nugget = 0 and Sill = 1

Chase Group

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	30	30		17	Poor*	Chase
1	25	25		17	Poor*	Chase
2	25	25		17	Poor*	Chase
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	27	23	11	16	Poor, same as F7*	Poor, same as F7*
10	25	21	11	21	Chase	Chase

Major axis is average for Chase or Wolfcamp (Chase & Council Grove)
Minor axis is 5/6th of major (as in Geomod3)
Azimuth = 11 degrees, as in Geomod 3
Rationale:
Chase Used average for Wlfcmp (Chase & Council Grove)
Wolfcam Used average for Chase
Poor* One HZ variogram in Chase F0-F2 = 29902.
*F9 variogram parameters modified later for more deterministic outcome

Note: We did experiment with short horizontal ranges for Lithofacies 0-2, but the distribution of facies in the model were unreasonable.

Diversions from rules for Chase

1. Krider: reduced vertical proportions significantly for F9 and changed ranges 50/42/10

2. Winfield: reduced vertical proportions significantly for F9 and changed ranges 50/42/10

3. FtRiley: reduced vertical proportions slightly for F10 and changed vertical range from 21 to 8

4. Wreford: zapped all F0-1-2 in property calculator (made =U) and reduced vertical range for F10 to 8

Chase Group – Porosity variograms

CHASE

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale HZ	Rationale VERT
0	42	42		25	Poor*	Cgrv, NA in Chase
1	35	35		15	Poor*	Wolfcamp
2	35	35		9	Poor*	Wolfcamp
3	32	27	11	16	Wlfcmp	Wolfcamp
4	32	27	11	16	NA, used F3	NA, used F4
5	36	30	11	21	Cgrv, NA in chase	Wolfcamp
6	27	23	11	17	Cgrv, NA in chase	Wolfcamp
7	34	28	11	14	Cgrv, NA in chase	Wolfcamp
8	NA	NA	NA	NA	None in Chase	None in Chase
9	39	33	11	20	Poor, same as F7	Chase
10	37	31	11	20	Chase	Chase

General Rules:

1. Horizontal major axes are average for either the Chase or Wolfcamp (Chase & Council Grove), except F0-2
2. Range for F0-2 are proportionately larger than for facies
3. For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.
4. Azimuth is 11 degrees, same as in Geomod3. This is approximate regional strike.
5. Vertical ranges are average for either the Chase or Wolfcamp (Chase & Council Grove).
6. Used shorter vertical ranges for facies that are out of place for the zone (5 feet)
7. Nugget = 0 and Sill = 1

Chase Group – Lithofacies variograms by zone (Gage and Matfield not shown)

Herington

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale Horizontal	Rationale Vertical
0	NA	NA	NA	NA	NA	NA
1	25	25		17	Poor*	Chase
2	25	25		17	Poor*	Chase
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	27	23	11	16	Poor, same as F7	Poor, same as F7
10	25	21	11	21	Chase	Chase

Krider

Facies	Major	Minor	Az	Vertical	Rationale Horizontal	Rationale Vertical
0	NA	NA	NA	NA	NA	NA*
1	NA	NA	NA	NA	NA	NA*
2	NA	NA	NA	NA	NA	NA*
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	**50**	**42**	**11**	**10**	***Modified after model review***	
10	25	21	11	21	Chase	Chase

**Present in minute amounts but did not model*

Odell

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale Horizontal	Rationale Vertical
0	30	30		17	Poor*	Chase
1	25	25		17	Poor*	Chase
2	25	25		17	Poor*	Chase
3	24	20	11	11	Wolfcamp	Chase
4	NA	NA	NA	NA	NA	NA
5	18	15	11	7	Wolfcamp	Chase
6	NA	NA	NA	NA	NA	NA
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	27	23	11	16	Poor, same as F7	Poor, same as F7
10	25	21	11	21	Chase	Chase

Winfield

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale Horizontal	Rationale Vertical
0	NA	NA	NA	NA	NA*	NA*
1	NA	NA	NA	NA	NA*	NA*
2	NA	NA	NA	NA	NA*	NA*
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	**50**	**42**	**11**	**10**	***Modified after model review***	
10	25	21	11	21	Chase	Chase

**Present in minute amounts but did not model*

FtRly

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale Horizontal	Rationale Vertical
0	30	30		**3***	Poor*	Chase
1	25	25		**3***	Poor*	Chase
2	25	25		**3***	Poor*	Chase
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	None in Chase	None in Chase
9	27	23	11	16	Poor, same as F7	Poor, same as F7
10	25	21	11	**8***	Chase	Chase

** Facies present in minute amounts. Reduced vertical range*

Wreford

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale Horizontal	Rationale Vertical
0	NA	NA	NA	NA	NA	NA*
1	NA	NA	NA	NA	NA	NA*
2	NA	NA	NA	NA	NA	NA*
3	24	20	11	11	Wolfcamp	Chase
4	18	15	11	7	Wolfcamp	Chase
5	18	15	11	7	Wolfcamp	Chase
6	30	25	11	16	Wolfcamp	Wolfcamp
7	27	23	11	16	Chase	Chase
8	NA	NA	NA	NA	NA	NA
9	NA	NA	NA	NA	NA	NA
10	25	21	11	**8****	Chase	Chase

** Zapped in calculator*

*** Facies present in minute amounts. Reduced vertical range*

Council Grove Group – Lithofacies variograms

General Rules:

1. Where available, horizontal major axes are average for Council Grove.
2. For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.
3. Azimuth is 11 degrees, same as in Geomod3. This is approximate regional strike.
4. Where available vertical ranges are average Council Grove.
5. Used shorter vertical ranges for facies that are out of place for the zone
6. Nugget = 0 and Sill = 1

Council Grove

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40		10	Poor est	Poor est
1	25	25		10	Cgrv	Cgrv
2	25	25		8	Cgrv	Cgrv
3	30	25	11	11	Cgrv	Cgrv
4	18	15	11	7	Cgrv	Cgrv
5	18	15	11	7	Cgrv	Cgrv
6	30	25	11	10	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, same as F7	NA, same as F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	21	Chase	Chase

F0	poor in analysis, estimated in modeling
F3	1 value = 43k, used 30k
F4	not enough data
F6	avg = 33k, used 30k
F8, 10	not enough data
F9	Not present

Diversions from rules for Council Grove

1. Did not model F>2 in A1sh through B5sh (did not zap, just excluded from modeling), but did model in Csh

2. Did not model F<3 in B1 and B5 LM, but did in the rest. A1 and C have additional 5th order cycles in places and the B2-3-4LMs are very thin in places (may actually be continental).

(may cancel each other)

Wreford and Council Grove Group – Porosity variograms

Wreford and Council Grove

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale HZ	Rationale VERT
0	42	42		15	Poor*	Cgrv, NA in chase
1	35	35		12	Poor*	Cgrv
2	35	35		9	Poor*	Wolfcamp
3	32	27	11	16	Wolfcamp	Wolfcamp
4	32	27	11	16	NA, used F3	NA, used F4
5	36	30	11	17	Cgrv, NA in chase	Cgrv
6	27	23	11	14	Cgrv, NA in chase	Cgrv
7	34	28	11	14	Cgrv, NA in chase	Cgrv
8	34	28	11	14	NA, used F7	NA, used F7
9	NA	NA	NA	NA	NA	Not in Cgrv
10	37	31	11	15	Chase	Reduced

General Rules:

1. Horizontal major axes are average for either the Chase or Wolfcamp (Chase & Council Grove), except F0-2
2. Range for F0-2 are proportionately larger than for facies
3. For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.
4. Azimuth is 11 degrees, same as in Geomod3. This is approximate regional strike.
5. Vertical ranges are average for either the Chase or Wolfcamp (Chase & Council Grove).
6. Used shorter vertical ranges for facies that are out of place for the zone (5 feet)
7. Nugget = 0 and Sill = 1

Council Grove Group – Lithofacies variograms by zone

A1_SH

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	10	Cgrv	Cgrv
3-10	NA	NA	NA	NA	Not modeled*	Not modeled*

** Some facies present in minute amounts. Did not model.*

Long-short A1LM

A1_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	3	Poor est	Poor est
1	25	25	NA	3	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Cgrv
3	30	25	11	7	Cgrv	Cgrv
4	18	15	11	7	Cgrv	Cgrv
5	18	15	11	7	Cgrv	Cgrv
6	30	25	11	7	Cgrv	Cgrv
7	18	15	11	7	Cgrv	Cgrv
8	18	15	11	7	NA, =F7	NA, =F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	7	Chase	Chase

B1_SH & B2_SH

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	10	Cgrv	Cgrv
3-10	NA	NA	NA	NA	Not modeled*	Not modeled*

** Some facies present in minute amounts. Did not model.*

B1_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	Not modeled*	Not modeled*
1	NA	NA	NA	NA	Not modeled*	Not modeled*
2	NA	NA	NA	NA	Not modeled*	Not modeled*
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	5	Chase	Chase

** Some facies present in minute amounts. Did not model.*

B3_SH & B4_SH

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	10	Cgrv	Cgrv
3-10	NA	NA	NA	NA	Not modeled*	Not modeled*

** Some facies present in minute amounts. Did not model.*

B2_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	NA	NA
1	25	25	NA	3	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Cgrv
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	NA	NA
10	25	21	11	5	Chase	Chase

Council Grove Group – Lithofacies variograms by zone

B3_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	NA	NA
1	25	25	NA	3	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Cgrv
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	NA	NA
10	25	21	11	5	Chase	Chase

B4_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	NA	NA
1	25	25	NA	3	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Cgrv
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	NA	NA
10	25	21	11	5	Chase	Chase

B5_SH

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	10	Cgrv	Cgrv
3-10	NA	NA	NA	NA	Not modeled*	Not modeled*

** Some facies present in minute amounts. Did not model.*

B5_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	Not modeled*	Not modeled*
1	NA	NA	NA	NA	Not modeled*	Not modeled*
2	NA	NA	NA	NA	Not modeled*	Not modeled*
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	5	Chase	Chase

** Some facies present in minute amounts. Did not model.*

C_SH

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	10	Cgrv	Cgrv
3	30	25	11	5	Cgrv	Cgrv
6	30	25	11	3	Cgrv	Cgrv
7	18	15	11	3	Cgrv	Cgrv

C_LM

Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Rationale: Horizontal	Rationale: Vertical
0	NA	NA	NA	NA	NA	NA
1	25	25	NA	3	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Cgrv
3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv
7	18	15	11	5	Cgrv	Cgrv
8	18	15	11	5	NA, =F7	NA, =F7
9	NA	NA	NA	NA	NA	NA
10	25	21	11	5	Chase	Chase