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
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- 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 <u>http://people.ku.edu/~gbohling/cpe940</u>
- 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

Property: F11_GM3 UJ 2000 Same settings for all zones Professional Control C	S Data Analysis with 'Fine Structure 660/Hrngtn-Winf 3D Grid'		- 🗆 🗙
Construction C	Property: 🔁 F11_GM3 [U] 🗾 Zones: Same settings for all zones	6 6 6 D	
Proportion Thekness MPRobability W Variograms For Facie: 3 Mu Site Result from variogram analysis: Provide C 272 Site Migor Direction Variation Provided Transe: 14000 Provide C 272 Site Migor Direction Variation Provided Transe: 14000 Provide C 272 Site Migor Direction Variation Provided Transe: 12 Provided C 272 Site Migor Direction Variation Provided Transe: 12 Provided C 272 Site Tolerance angle 183 3933 Lag distance: 21 Search ordly inside zone Lag distance: 10 Search ordly inside zone Lag distance: 10 Search ordly inside zone Tolerance angle 183 3933 Lag distance: 12 Search ordly inside zone D 10 D 2 D 2 D 2 D 2 D 2 D 2 D 2 D 2	🔄 🖼 🖓 🔛 🖉 🔛		
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Toterance angle 98.993 Lag distance: 21 Search only inside zone C Lag toterance: 50 % C	Band width: 0.01 ② Search radius: 20 No lags: 10		
Search only inside zone C Lag tolerance: 50 2 2 Search only inside zone C Lag toleran	Tolerance angle: 89.999 Lag distance: 2.1		
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			Cancel

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
- 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

G	eneral Rules:	Chase Gr	oup			Rationale		
1.	Horizontal major axes are average for either the Chase or Wolfcamp (Chase & Council Grove)	Facies 0 1	ft) 30 25 25	(k-ft) 30 25 25	Az	vertical (ft) 17 17 17	Horizontal Poor* Poor* Poor*	Vertical Chase Chase Chase
2.	For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.	2 3 4 5 6 7	23 24 18 18 30 27	20 15 15 25 23	11 11 11 11 11	11 7 7 16 16	Wolfcamp Wolfcamp Wolfcamp Wolfcamp Chase	Chase Chase Chase Wolfcamp Chase
3.	Azimuth is 11 degrees, same as in Geomod3. This is approximate regional strike.	8 9 10	NA 27 25	NA 23 21	NA 11 11	NA 16 21	None in Chase Poor, same as F7* Chase	None in Chase Poor, same as F7* Chase

4. Vertical ranges are average

5. Used shorter vertical ranges

6. Nugget = 0 and Sill = 1

Wolfcamp (Chase & Council

for facies that are out of place

for either the Chase or

Grove).

for the zone

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					Rationale			
	Major	Minor		Vertical				
Facies	(k-ft)	(k-ft)	Az	(ft)	HZ	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)

	- I	Major (k	Minor		Vertical			Winfield		
Fac	ies	ft)	(k-ft)	Az	(ft)	Horizontal	Vertical		Major (k	Minor
	0	NÁ	NA	NA	ŇÁ	NA	NA	Facies	ft)	(k-ft)
	1	25	25		17	Poor*	Chase	0	NA	NA
	2	25	25		17	Poor*	Chase	1	NA	NA
	3	24	20	11	11	Wolfcamp	Chase	2	NA	NA
	4	18	15	11	7	Wolfcamp	Chase	3	24	20
	5	18	15	11	7	Wolfcamp	Chase	4	10	15
	6	30	25	11	16	Wolfcamp	Wolfcamp	5	30	25
	7	27	23	11	16	Chase	Chase	7	27	23
	8	NA	NA	NA	NA	None in Chase	None in Chase	8	NA	NA
	9	27	23	11	16	Poor, same as F7	Poor, same as F7	9	50	42
	10	25	21	11	21	Chase	Chase	10	25	21
	10	20	21		~ '	onuso	Ondoc		*Drocont	in minu

,	I	Major (k	Minor		Vertical		
FtRIv							Rationale
		*Present i	n minute	e amounts	s but did n	ot model	
	10	25	21	11	21	Chase	Chase
	9	50	42	11	10	Modified after	model review
	8	NA	NA	NA	NA	None in Chase	None in Cl
	7	27	23	11	16	Chase	Chase
	6	30	25	11	16	Wolfcamp	Wolfcamp
	5	18	15	11	7	Wolfcamp	Chase
	4	18	15	11	7	Wolfcamp	Chase

Vertical

(ft)

NA

NA

NA

11

Horizontal

Wolfcamp

NA*

NA*

NA*

Az

NA

NA

NA

11

-	Major (k	Minor		Vertical			
Facies	ft)	(k-ft)	Az	(ft)	Horizontal	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	
	* Eacios r	procont in	n minute	amounte	Poducod vortical rango		

Facies present in minute amounts. Reduced vertical rande

nalo	Wreford						Rationale
liale		Major (k	Minor		Vertical		
M. C. I	Facies	ft)	(k-ft)	Az	(ft)	Horizontal	Vertical
vertical	0	NA	NA	NA	NA	NA	NA*
Chase	1	NA	NA	NA	NA	NA	NA*
Chase	2	NA	NA	NA	NA	NA	NA*
Chase	3	24	20	11	11	Wolfcamp	Chase
Chase	4	18	15	11	7	Wolfcamp	Chase
NA	5	18	15	11	7	Wolfcamp	Chase
Chase	6	30	25	11	16	Wolfcamp	Wolfcamp
NA	7	27	23	11	16	Chase	Chase
NA	8	NA	NA	NA	NA	NA	NA
Chase	9	NA	NA	NA	NA	NA	NA
None in Chase	10	25	21	11	8**	Chase	Chase
Poor, same as F7		*Zapped	l in calcul	ator			
Chase		** Facies	present i	in minut	e amounts.	Reduced ver	tical range

Herington

Major	Minor	Az	Vertical	Horizontal
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA
24	20	11	11	Wolfcamp
18	15	11	7	Wolfcamp

*Present in minute amounts but did not model

Vertical NA* NA*

Rationale

NA* Chase Chase Wolfcamp Chase 15 11 7 25 11 16 Wolfcamp Wolfcamp 23 11 Chase Chase 16 None in Chase None in Chase NA NA NA 42 Modified after model review 11 10 21 11 21 Chase Chase

Odell

Krider

Facies

0

1 2

3

4

5

6

7

8

9

10

18

30

27

NA

50

25

	Major (k	Minor		Vertical		
Facies	ft)	(k-ft)	Az	(ft)	Horizontal	Ve
0	30	30		17	Poor*	Ch
1	25	25		17	Poor*	Ch
2	25	25		17	Poor*	Ch
3	24	20	11	11	Wolfcamp	Ch
4	NA	NA	NA	NA	NA	NA
5	18	15	11	7	Wolfcamp	Ch
6	NA	NA	NA	NA	NA	NA
7	27	23	11	16	Chase	Ch
8	NA	NA	NA	NA	None in Chase	No
9	27	23	11	16	Poor, same as F7	Po
10	25	21	11	21	Chase	Ch

Rational

Rationale

Vertical

NA*

NA*

NA*

Chase

Chase

Council Grove Group – Lithofacies variograms

4.

5.

6.

strike.

Grove.

Where available vertical

Used shorter vertical

ranges for facies that are out of place for the zone

Nugget = 0 and Sill = 1

ranges are average Council

Gen	eral Rules:	Council Grove			Rationale			
1.	Where available, horizontal major axes are average for Council Grove.	Facies 0 1 2	Major (k-ft) 40 25 25	Minor (k-ft) 40 25 25	Az	Vertical (ft) 10 10 8	Horizontal Poor est Cgrv Cgrv	Vertical Poor est Cgrv Cgrv
2.	For lithofacies 3-10, minor axis is 5/6th of major (as in Geomod3). Seemed to work fine in Geomod3.	3 4 5 6 7 8	30 18 18 30 18 18	25 15 15 25 15 15	11 11 11 11 11 11	11 7 7 10 5 5	Cgrv Cgrv Cgrv Cgrv Cgrv NA, same as F7	Cgrv Cgrv Cgrv Cgrv Cgrv NA, same as F7
3.	Azimuth is 11 degrees, same as in Geomod3. This is approximate regional	9 10	NA 25	NA 21	NA 11	NA 21	None in Cgrv Chase	None in Cgrv Chase

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

Diversions from rules for Council Grove

- Did not model F>2 in A1sh through B5sh (did not zap, just excluded from modeling), but did model in Csh
- 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 Co	uncil G	rove		Rationale			
	Major (k	Minor		Vertical	l			
Facies	ft)	(k-ft)	Az	(ft)	HZ	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
- 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					R	ationale
Facies	Major (k-ft)	Minor (k-ft)	Az	Vertical (ft)	Horizontal	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 pre	esent in	minute am	ounts. Did not moo	del.

Long-short A1LM

A1 LM

Rationale

—	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	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

& B2_S	H	Rationale				
Major	Minor		Vertical			
(k-ft)	(k-ft)	Az	(ft)	Horizontal	Vertical	
40	40	NA	10	Poor est	Poor est	
25	25	NA	10	Cgrv	Cgrv	
25	25	NA	10	Cgrv	Cgrv	
NA	NA	NA	NA	Not modeled*	Not modeled*	
	B2_SI Major (k-ft) 40 25 25 NA	B2_SH Major Minor (k-ft) (k-ft) 40 40 25 25 25 25 NA NA	B2_SH Major Minor (k-ft) (k-ft) Az 40 40 NA 25 25 NA 25 25 NA NA NA NA	AB2_SH Vertical Major Minor Vertical (k-ft) (k-ft) Az (ft) 40 40 NA 10 25 25 NA 10 25 25 NA 10 NA NA NA NA	B2_SH MajorMinorVertical(k-ft)(k-ft)Az(ft)Horizontal4040NA10Poor est2525NA10Cgrv2525NA10CgrvNANANANANot modeled*	

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

B1_LM						Rationale
	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	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	NĀ, =F7	NĂ, =F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	5	Chase	Chase
	* Como	factor nre	a a matim	minute and	aunta Diduatur	adal

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

B3_SH & B4_SH

	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	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 pre	esent in l	minute am	ounts. Did not model	_

Rationale

B2 LM Rationale Major Minor Vertical (k-ft) Facies (k-ft) Az (ft) Horizontal Vertical NA NA NA NA NA NA 0 Cgrv 1 25 25 NA 3 Cgrv 2 25 3 Cgrv 25 NA Cgrv 3 30 25 11 5 Cgrv Cgrv 4 18 15 5 11 Cgrv Cgrv 5 18 15 11 5 Cgrv Cgrv 6 30 25 11 5 Cgrv Cgrv 7 5 18 15 11 Cgrv Cgrv 8 5 18 15 11 NA, =F7 NA, =F7 9 NA NA NA NA NA NA 10 25 21 5 11 Chase Chase

Council Grove Group – Lithofacies variograms by zone

B3_LM						Rationale
	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	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_LM						Rationale
	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	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	NĀ, =F7	NA, =F7
9	NA	NA	NA	NA	None in Cgrv	None in Cgrv
10	25	21	11	5	Chase	Chase
	* Como	factor are	a a mat im	maine de ana	aunta Diduatu	nodol

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

B4_LM						Rationale	C SH						Rationale
	Major	Minor		Vertical			•_•	Major	Minor		Vertical		
Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	Vertical	Facies	(k-ft)	(k-ft)	Az	(ft)	Horizontal	Vertical
0	NA	NA	NA	NA	NA	NA	0	40	40	NA	10	Poor est	Poor est
1	25	25	NA	3	Cgrv	Cgrv	1	25	25	NA	10	Cgrv	Cgrv
2	25	25	NA	3	Cgrv	Carv	2	25	25	NA	10	Cgrv	Cgrv
3	30	25	11	5	Carv	Carv	3	30	25	11	5	Cgrv	Cgrv
4	18	15	11	5	Carv	Carv	6	30	25	11	3	Cgrv	Cgrv
5	18	15	11	5	Cgrv	Cgrv	7	18	15	11	3	Cgrv	Cgrv
6	30	25	11	5	Cgrv	Cgrv	с I М					Potionala	
7	18	15	11	5	Cgrv	Cgrv		Major	Minor		Vartical	Rationale	
8	18	15	11	5	NA, =F7	NA, =F7	Engine	(k ft)	(k ft)	۸-	(f+)	Horizontal	Vortical
9	NA	NA	NA	NA	NA	NA	racies			MZ NIA		NA	NIA
10	25	21	11	5	Chase	Chase	1	25	25	NΔ	3	Carv	Carv
							2	25	25	NA	3	Carv	Carv
B5 SH						Rationale	3	30	25	11	5	Carv	Carv
00_011	Major	Minor		Vortical		Rationale	4	18	15	11	5	Carv	Carv
Fasias	(1, ft)		^ _		l la nime na tal	Vartiaal	5	18	15	11	5	Carv	Carv
Facles	(K-IT)	(K-IT)	AZ	(11)	Horizontai	vertical	6	30	25	11	5	Carv	Carv
0	40	40	NA	10	Poor est	Poor est	7	18	15	11	5	Carv	Carv
1	25	25	NA	10	Cgrv	Cgrv	8	18	15	11	5	NA =F7	NA =F7
2	25	25	NA	10	Cgrv	Cgrv	q	NΔ	NΔ	NΔ	NΔ	NA	NA, EL 7
3-10	NA	NA	NA	NA	Not modeled*	Not modeled*	10	25	21	11	5	Chase	Chase
	* Como	facion pre	soont in	minute om	ounto Did not	model	10	_0		••	Ū	0	enace

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