Predictive Statistical Indicators of Potential Target Reservoirs in West Siberia for Enhanced Oil Production

and

Regression Models of Oil Production

J. H. Doveton and J. C. Davis

Prepared for:

Technical report for SNS Energy
Energy and Economic Reform in the Former Soviet Union: Implications for Production, Consumption and Exports, and the International Energy Markets
A study by L. Dienes, I. Dobozi, and M. Radetzki

KANSAS GEOLOGICAL SURVEY
Open File Report 92-58
November, 1992

38p.

PREDICTIVE STATISTICAL INDICATORS OF POTENTIAL TARGET RESERVOIRS IN WEST SIBERIA FOR ENHANCED OIL PRODUCTION

Statistical correlations were computed between geologic and engineering descriptor variables from reservoirs in all tabulated West Siberian oilfields and their reported oil yields. The variables most strongly linked with oil yield are, in order of importance: permeability, initial gas-oil ratio, porosity, absolute height, overall formation thickness, reservoir height. Formation pressure and formation roof depth were highly correlated with absolute depth. Formation temperature showed a low correlation with oil yield.

These statistical results are readily interpretable in terms of standard reservoir engineering concepts. They imply that oil yields are numerically related with transmissibility of the formation to fluid flow (permeability), oil fluid characteristics, such as viscosity (initial oil-gas ratio), formation pore volume (porosity), depth location of the reservoir (absolute height), and the reservoir size measures of overall formation thickness and reservoir height. Collectively, these descriptors are highly useful for predictions of theoretical productivity for analytical comparisons with actual oil yields. A crucial variable that is missing from data currently available is some estimate of reservoir areal dimension. Consequently, interpretations of the numerical results of this report must incorporate this as an additional consideration. So, for example, a reservoir that appears to produce significantly less than another with equivalent descriptive properties may simply be smaller in areal size.

Although several reservoir descriptors were correlated significantly with oil yield, most of the correlation coefficient values were low. In order to enhance predictive power, the six most important descriptor variables were used collectively in a multiple regression analysis as predictors of oil yield. Further, the total West Siberian reservoir data set was subdivided into four parts for separate regression analysis. By this means, excessive mingling of different reservoir populations would be reduced and the predictive power of resultant equations would be improved. The requirement of six predictor variables in the multiple regression analysis reduced the total number to a sample of 204 West Siberian reservoirs. The allocation of regions, number of reservoirs analyzed and fit of the regression equation to the oil yield data are summarized below for each set:

SET	Regions	Reservoirs	Regression fit
1:	Nizhnevartov NGR	51	32.0%
2:	Surgut NGR, Salym NGR	58	37.6%
3:	Venga-Pur NGR, Gubkin NGR, Urengoy NGR, South Yamal NGR, Aleksandrovskiy NGR, Shaim NGR	50	42.1%
4.:	Krasnoleninskiy NGR, Nizhnevartovsk NGR [Tomsk Oblast], Aleksandrovskiy NGR, Vasyugan NGR, Pudinskiy NGR, Kaymysovskiy NGR, Mezhovskiy NGR, Silga NGR, Payduga NGR	45	35.0%

The regression equations allow a prediction of the oil yield that would be associated with any value set of the reservoir descriptor variables. In the following tables, each reservoir is identified through its field name and reservoir age. The values record the reported oil yield, the regression prediction of oil yield, and the residual (prediction minus actual yield). Because the regression is fitted to the data as a least squared error prediction, residuals will be both positive and negative. This property contrasts reservoirs that are producing either more or less than would be expected on average for any measurement combination of reservoir descriptors. The negative residuals flag reservoirs that have potential for increased production by an amount equivalent to the residual magnitude. Alternatively, the prediction may be contrasted with the actual oil yield.in a proportional measure. Reservoirs that are indexed with either a single or double asterisk are those determined by the regression analysis to be outliers. Their anomalous characteristics make them distinctly different from other reservoirs in the set, so that associated predictions should be viewed with special caution.

Following each regression prediction tabulation is a classification "map" of the reservoirs produced by multidimensional scaling. The relative proximity of the reservoirs on the map is a reflection of their similarity based on the six predictor variables used in the regression analysis weighted by their Spearman rank correlation with oil yield. The diameter of each "bubble" is scaled to the reported oil yield ; the bubble number is an identification matched with the first column of the regression listing ; those reservoirs suggested by the regression analysis to have potential for increased production are identified by underscored numbers. The maps should be considered in conjunction with the regression prediction listing as an aid to locating clusters of similar reservoirs and relating these to relative oil yields.

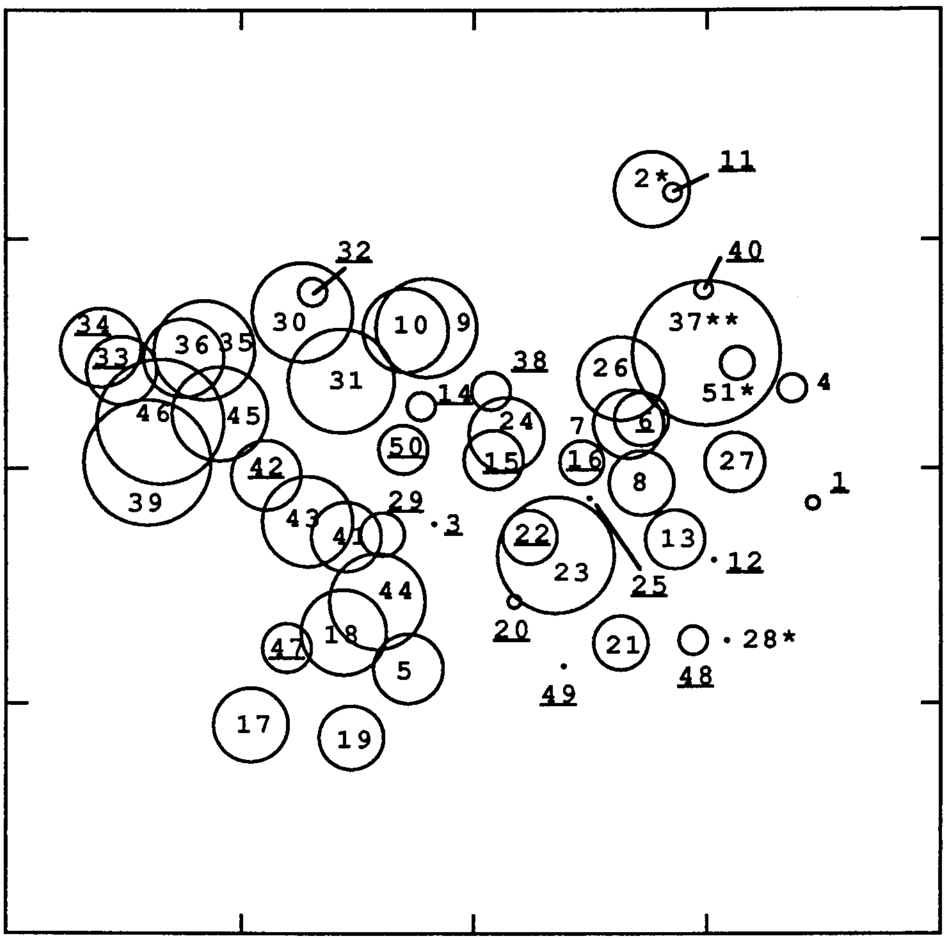
Finally, a whole-model response plot is shown for each each data set, in which predicted oil yields are plotted against reported oil yields. The dashed curves are confidence intervals, so that the numbered points are those reservoirs that are indicated to have significant potential for increased yields. The identification numbers on the plot are matched with the reservoir names in the key listing.

WEST SIBERIA DATA SET 1
(NIZHNEVARTOV NGR)

ID	NGR	FIELD/RES.AGE		OILYIELD	PRED.	RESID.	
1	Nizhnev	Bolshekotuk	BV8	35.0	49.1	-14.1	
2	Nizhnev	Povkhovskoye	BV8	154.0	100.5	53.4	*
3	Nizhnev	Vatyegansko	AV1	17.0	126.8	-109.8	
4	Nizhnev	Vatyegansko	Yu1-1	61.8	59.7	2.0	
5	Nizhnev	Pokachevsko	AV1	140.0	133.5	6.4	
6	Nizhnev	Pokachev C	BV6	108.0	120.4	-12.4	
7	Nizhnev	Pokachev CE	BV6	138.0	119.7	18.2	
8	Nizhnev	Pokachev E	BV6	130.0	108.8	21.1	
9	Nizhnev	Pokachev N	BV8	200.0	155.6	44.3	
10	Nizhnev	Pokachev C	BV8	169.0	148.8	20.1	
11	Nizhnev	Pokachevsko	Yu1-1	43.0	89.9	-46.9	
12	Nizhnev	South Pokach	AV1	12.6	97.5	-84.9	
13	Nizhnev	South Pokach	BV6	120.0	99.3	20.6	
14	Nizhnev	South Pokach	BV8	67.0	142.7	-75.7	
15	Nizhnev	Lokosovskoye	BV6	119.0	125.1	-6.1	
16	Nizhnev	Lokosovskoye	BV7	90.0	117.6	-27.6	
17	Nizhnev	N Pokurs	AV1	148.0	146.7	1.2	
18	Nizhnev	N Pokurs	AV2	172.0	132.1	39.8	
19	Nizhnev	N Pokurs	AV4	133.7	125.8	7.8	
20	Nizhnev	N Pokurs	BV0	36.0	113.9	-77.9	
21	Nizhnev	N Pokurs	BV1	110.8	77.5	33.3	
22	Nizhnev	N Pokurs C	BV6	115.5	131.4	-15.9	
23	Nizhnev	N Pokurs W	BV6	230.0	117.3	112.6	
24	Nizhnev	N Pokurs E	BV6	147.0	129.7	17.2	
25	Nizhnev	N Pokurs W	BV8	12.0	114.1	-102.1	
26	Nizhnev	N Pokurs E	BV8	170.0	119.8	50.1	
27	Nizhnev	NPokurs	BV9	118.0	88.2	29.7	
28	Nizhnev	Yermakovsko	AV1	2.8	(-19.0)	21.8	*
29	Nizhnev	Aganskoye	BV6	90.0	129.3	-39.3	
30	Nizhnev	Aganskoye	BV8	201.0	164.2	36.7	
31	Nizhnev	Aganskoye	BV9	210.0	153.5	56.4	
32	Nizhnev	Samotlor	AV1	66.0	142.1	-76.1	
33	Nizhnev	Samotlor	AV2	137.6	185.3	-47.7	
34	Nizhnev	Samotlor	AV4	162.6	207.5	-44.9	
35	Nizhnev	Samotlor	BV8	200.0	153.7	46.2	
36	Nizhnev	Samotlor	BV10	160.0	159.0	0.9	
37	Nizhnev	Megion	AV1	288.0	106.3	181.6	**
38	Nizhnev	Megion	AV2	80.0	143.6	-63.6	
39	Nizhnev	Megion	BV8	250.0	174.5	75.4	
40	Nizhnev	Megion	Yu1-1	46.8	107.5	-60.7	
41	Nizhnev	Vatinskoye	AV1	140.0	125.1	14.8	
42	Nizhnev	Vatinskoye	AV2	140.0	150.6	-10.6	
43	Nizhnev	Vatinskoye	BV0	180.0	143.7	36.2	
44	Nizhnev	Vatinskoye	BV1	185.0	135.6	49.3	
45	Nizhnev	Vatinskoye	BV7	190.0	177.7	12.2	
46	Nizhnev	VatinskoyeN	BV7	250.0	178.4	71.5	
47	Nizhnev	Vartovsk-Sos	BV10	102.0	140.0	-38.0	
48	Nizhnev	Tyumen	BV3	63.7	67.4	-3.7	
49	Nizhnev	Tyumen	BV5	13.3	111.4	-98.1	

50	Nizhnev Tyumen	BV6	102.0	140.7	-38.7	
51	Nizhnev Gunyegansko	BV8	72.8	59.0	13.7	*

* = large leverage ; ** = outlier - these reservoirs are considered by the regression analysis to be anomalous for prediction purposes.

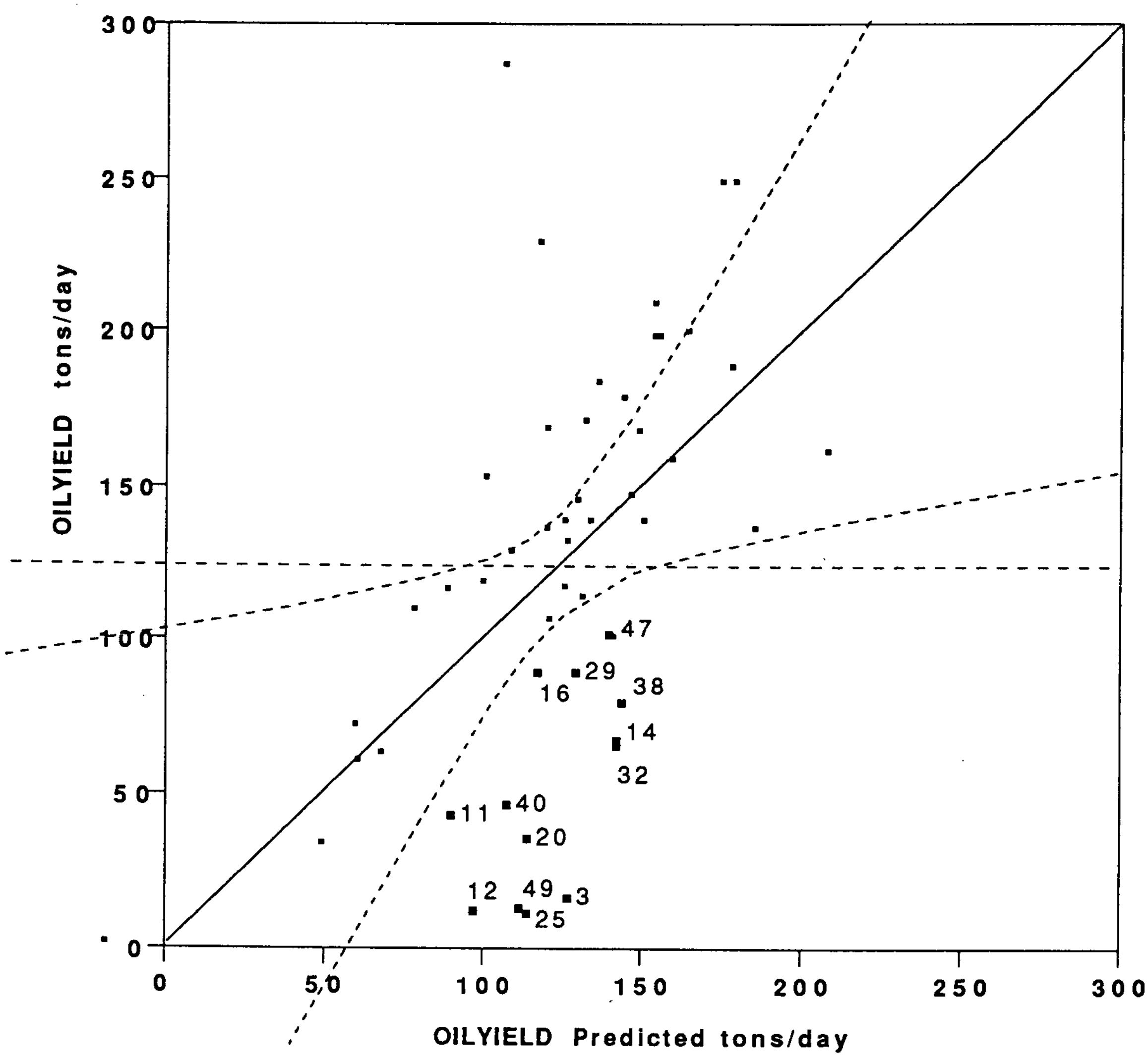


MULTIDIMENSIONAL SCALING MAP OF OIL RESERVOIRS IN DATA SET 1

The bubble size is scaled so that the radius is proportional to reported oil yield. Reservoirs considered to be outside the normal prediction range by the multiple regression analysis are flagged with *. The reference numbers are keyed to the reservoir names in the listing. The numbers that are underlined signify those reservoirs indicated by regression analysis to be producing less than their potential.

WEST SIBERIA DATA SET 1

Whole model response plot of predicted oil yield versus reported oil yield. The lower dashed curve is the significance limit for reservoirs whose predicted oil yield are significantly greater than their reported yield. These reservoirs are identified in the listing.



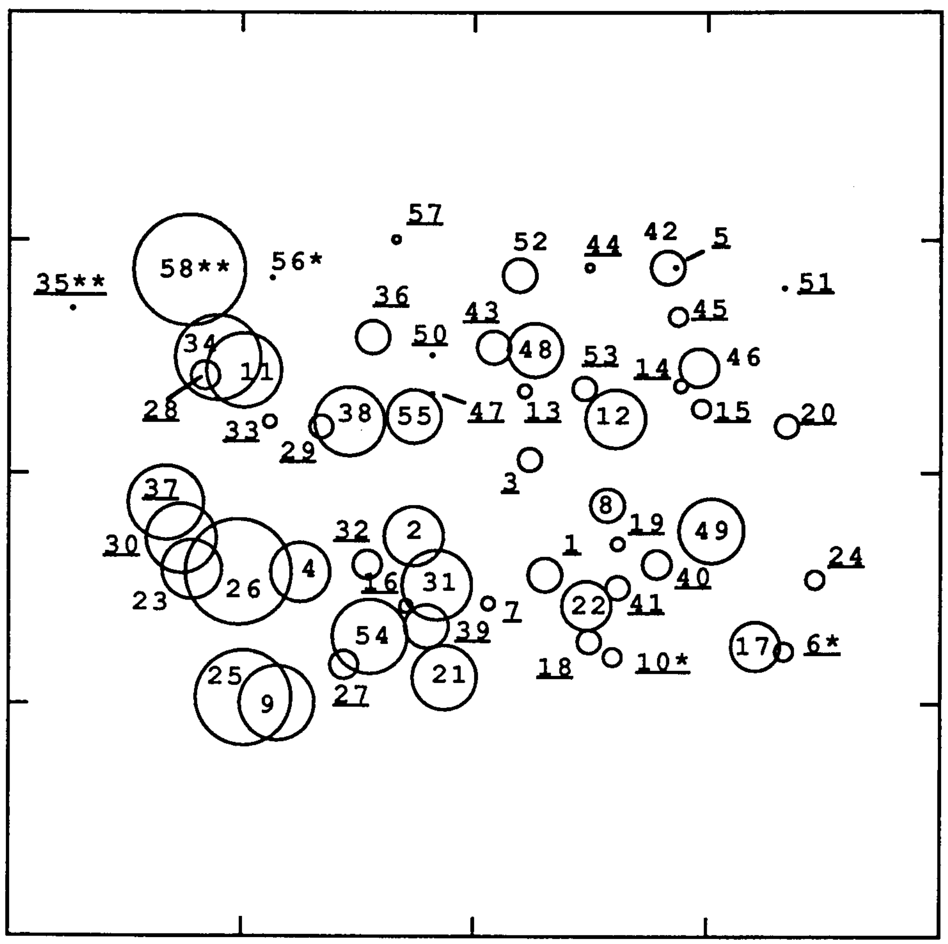
FIELD	RESERVOIR	YIELD	PREDICTION	ID
Vatyegansko	AV1	17	126.	3
Pokachevsko	Yu1-1	43	89.	11
South Pokach	AV1	12.6	97.	12
South Pokach	BV8	67	142.	14
Lokosovskoye	BV7	90	117.	16
North Pokurs	BV0	36	113.	20
North Pokurs	BV8	12	114.	25
Aganskoye	BV6	90	129.	29
Samotlor	AV1	66	142.	32
Megion	AV2	80	143.	38
Megion	Yu1-1	46.8	107.	40
Vartovsk-Sos	BV10	102	140.	47
Tyumen	BV5	13.3	111.	49

WEST SIBERIA DATA SET 2
(SURGUT NGR AND SALYM NGR)

ID	NGR	FIELD/RES.AGE		OILYIELD	PRED.	RESID.	
1	Surgut	Kholmogorsko	BS10	74.0	91.3	-17.3	
2	Surgut	Kholmogorsko	BS11	132.0	88.2	43.7	
3	Surgut	Kogolymskoye	Yu1	60.0	99.5	-39.5	
4	Surgut	Savuyskoye	BS11	125.0	124.3	0.6	
5	Surgut	Saygatinskoy	BS1	18.9	48.9	-30.0	
6	Surgut	Fedorovskoye	AS5	43.1	77.3	-34.2	*
7	Surgut	Fedorovskoye	AS8	38.1	78.8	-40.7	
8	Surgut	Fedorovskoye	BS1	82.0	55.4	26.5	
9	Surgut	Fedorovskoye	BS11	155.0	151.8	3.1	
10	Surgut	East Mokhovo	AS5	43.1	95.2	-52.1	*
11	Surgut	East Mokhovo	BS11	155.0	91.6	63.3	
12	Surgut	Yaunlorskoye	AS9	129.7	61.2	68.4	
13	Surgut	Yaunlorskoye	BS10	40.7	54.2	-13.5	
14	Surgut	Yaunlorskoye	BS11	41.0	42.5	-1.5	
15	Surgut	North Minchi	AS7	47.0	52.6	-5.6	
16	Surgut	Bystrinskoye	AS7	36.0	90.3	-54.3	
17	Surgut	Bystrinskoye	BS1	106.5	76.3	30.1	
18	Surgut	Bystrinskoye	BS2	55.0	88.7	-33.7	
19	Surgut	North Surgut	BS1	33.0	60.3	-27.3	
20	Surgut	Vershinnoye	BS10	55.0	57.8	-2.8	
21	Surgut	West Surgut	BS1	136.0	96.4	39.5	
22	Surgut	West Surgut	BS2	103.0	65.4	37.5	
23	Surgut	South Surgut	BS10	128.0	125.9	2.0	
24	Surgut	Ust Balyk	AS7	44.0	68.4	-24.4	
25	Surgut	Ust Balyk	BS1	200.0	146.7	53.2	
26	Surgut	Ust Balyk	BS3	220.0	116.8	103.1	
27	Surgut	Ust Balyk	BS10	65.0	76.8	-11.8	
28	Surgut	Mamontovskoy	AS4	69.0	113.4	-44.4	
29	Surgut	Mamontovskoy	BS8	55.0	115.5	-60.5	
30	Surgut	Mamontovskoy	BS10	150.0	165.8	-15.8	
31	Surgut	Teplovskoye	BS6	150.0	92.5	57.4	
32	Surgut	Teplovskoye	BS8	70.0	115.0	-45.0	
33	Surgut	Malobalyksko	AS4	41.0	92.3	-51.3	
34	Surgut	Malobalyksko	AS5	180.0	118.7	61.2	
35	Surgut	Malobalyksko	BS16	7.6	99.3	-91.7	**
36	Surgut	South Balyk	BS1	75.6	103.8	-28.2	
37	Surgut	South Balyk	BS10	155.0	179.5	-24.5	
38	Surgut	Central Baly	BS10	144.0	99.9	44.0	
39	Surgut	Lyantorskoye	AS9	95.6	99.2	-3.6	
40	Surgut	Taybinskoye	AS9	67.0	73.8	-6.8	
41	Surgut	Taybinskoye	AS9	53.4	81.0	-27.6	
42	Surgut	Alekhinskoye	AS8	76.0	67.3	8.6	
43	Surgut	Alekhinskoye	AS9	76.0	79.3	-3.3	
44	Surgut	Lower Sortym	AS11	25.0	70.7	-45.7	
45	Surgut	East Surgut	BS10	44.0	61.7	-17.7	
46	Surgut	East Surgut	Yu1	90.0	55.7	34.2	
47	Surgut	East Surgut	Yu2	12.1	71.9	-59.8	
48	Surgut	Shirokovskoy	Yu1	116.6	102.7	13.8	
49	Surgut	South Yaguns	BS11	137.4	62.7	74.6	

50	Surgut	Kochevskoye	Yu1	10.1	70.5	-60.4	
51	Surgut	Sorymskoye	BS16	4.0	46.2	-42.2	
52	Salym	Pravdinskoye	AS9	77.0	77.9	-0.9	
53	Salym	Pravdinskoye	BS4	53.3	55.2	-1.9	
54	Salym	Pravdinskoye	BS6	158.0	101.4	56.5	
55	Salym	Pravdinskoye	BS8	120.0	65.3	54.6	
56	Salym	Salym	BS4	18.0	-33.4	51.4	*
57	Salym	Salym	BS6	24.4	34.8	-10.4	
58	Salym	Salym	Yu0	232.0	128.0	103.9	**

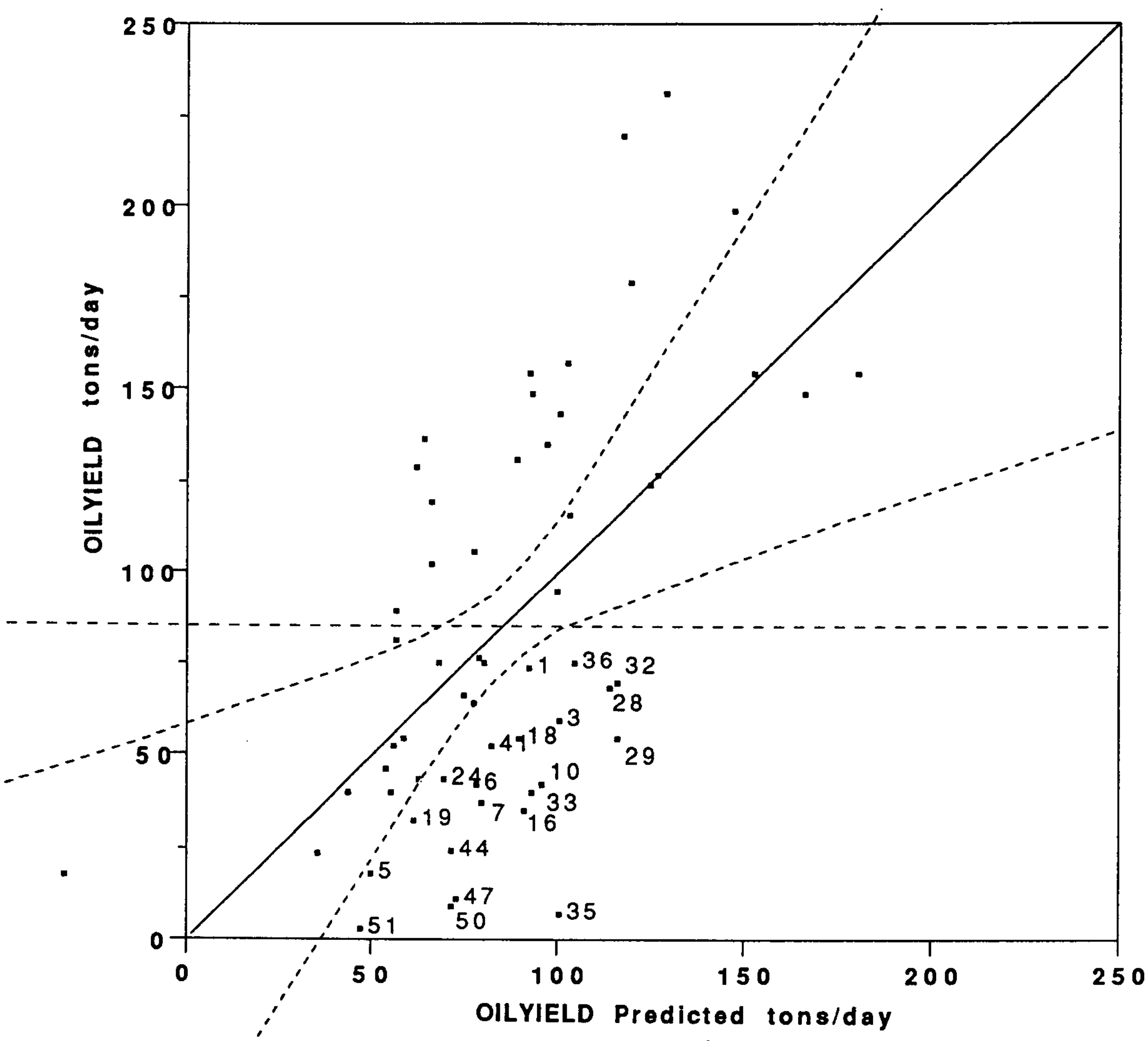
* = large leverage ; ** = outlier - these reservoirs are considered by the regression analysis to be anomalous for prediction purposes.



MULTIDIMENSIONAL SCALING MAP OF OIL RESERVOIRS IN DATA SET 2
The bubble size is scaled so that the radius is proportional to reported oil yield. Reservoirs considered to be outside the normal prediction range by the multiple regression analysis are flagged with *. The reference numbers are keyed to the reservoir names in the listing. The numbers that are underlined signify those reservoirs indicated by regression analysis to be producing less than their potential.

WEST SIBERIA DATA SET 2

Whole model response plot of predicted oil yield versus reported oil yield. The lower dashed curve is the significance limit for reservoirs whose predicted oil yield are significantly greater than their reported yield. These reservoirs are identified in the listing.



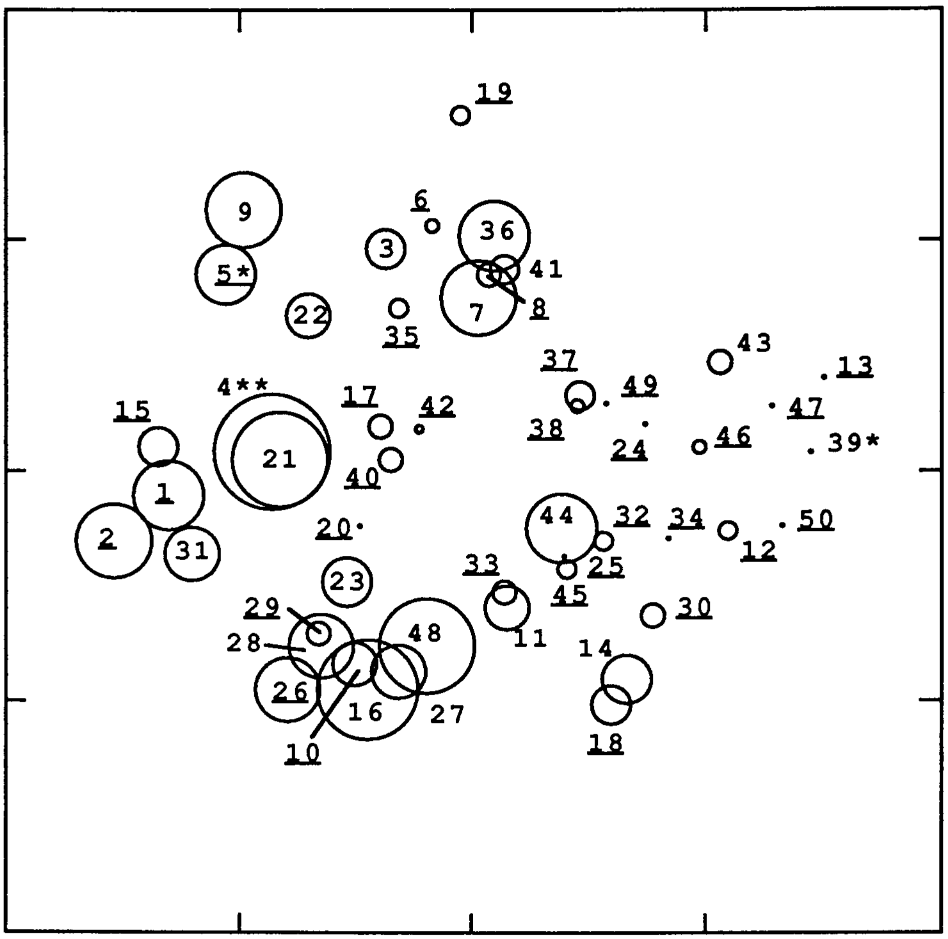
FIELD	RESERVOIR	YIELD	PREDICTION	ID
Kholmogorsko	BS10	74	91.	1
Kogolymskoye	Yu1	60	99.	3
Saygatinskoy	BS1	18.9	48.	5
Fedorovskoye	AS5	43.1	77.	6
Fedorovskoye	AS8	38.1	78.	7
East Mokhovo	AS5	43.1	95.	10
Bystrinskoye	AS7	36	90.	16
Bystrinskoye	BS2	55	88.	18
North Surgut	BS1	33	60.	19
Ust Balyk	AS7	44	68.	24
Mamontovskoy	AS4	69	113.	28
Mamontovskoy	BS8	55	115.	29
Teplovskoye	BS8	70	115.	32
Malobalyksko	AS4	41	92.	33
Malobalyksko	BS16	7.6	99.	35
South Balyk	BS1	75.6	103.	36
Taybinskoye	AS9	53.4	81.	41
Lower Sortym	AS11	25	70.	44
East Surgut	Yu2	12.1	71.	47
Kochevskoye	Yu1	10.1	70.	50
Sorymskoye	BS16	4	46.	51

WEST SIBERIA DATA SET 3
(VENGA-PUR NGR, GUBKIN NGR, URENGOY NGR, SOUTH YAMAL NGR, ALEKSANDROVSKIY NGR, AND SHAIM NGR)

ID	NGR	FIELD/RES.	AGE	OILYIELD	PRED.	RESID.	
1	Venga-P	Varyeganskoy	BV7	150.0	163.5	-13.5	
2	Venga-P	Varyeganskoy	BV8	155.0	194.0	-39.0	
3	Venga-P	Varyeganskoy	Yu1-2	85.6	70.0	15.5	
4	Venga-P	North Varyeg	BV8	246.0	106.2	139.7	**
5	Venga-P	North Varyeg	Yu1	130.0	137.0	-7.0	*
6	Venga-P	Tagra	Yu1	32.0	80.3	-48.3	
7	Venga-P	Vanyeganskoy	Yu1	165.0	77.0	87.9	
8	Venga-P	Novomolodez	Yu1-1	61.6	65.1	-3.5	
9	Gubkin	Gubkin	Yu1	162.4	108.6	53.7	
10	Gubkin	Muravlenkov	BS11	97.5	146.6	-49.1	
11	Gubkin	Sutorminsko	BS8	102.8	99.8	2.9	
12	Gubkin	Sutorminsko	BS9-1	43.0	60.7	-17.7	
13	Gubkin	Sutorminsko	BS10	16.4	29.1	-12.7	
14	Gubkin	Sutorminsko	BS10-1	110.9	84.9	25.9	
15	Urengoy	Urengoy N	BU10	89.0	153.9	-64.9	
16	South Yl	Novoportovs	NP1	215.0	126.1	88.8	
17	Aleksa	Khokhryakovs	Yu1	60.0	97.1	-37.1	
18	Aleksa	South Vakh	Yu1	85.0	93.1	-8.1	
19	Aleksa	North Khokhr	Yu1-1	48.0	62.7	-14.7	
20	Shaim	Mulymyinskoy	P1	16.0	85.4	-69.4	
21	Shaim	Trekhozernoy	P1	200.0	90.3	109.6	
22	Shaim	North Trekho	P1	100.0	64.5	35.4	
23	Shaim	South Mortym	P1	112.0	94.2	17.7	
24	Shaim	W Mortymy N	P1	20.0	31.3	-11.3	
25	Shaim	W Mortymy S	P1	20.0	69.4	-49.4	
26	Shaim	North Mortym	P1	139.0	147.6	-8.6	
27	Shaim	North Mortym	P1	120.0	120.5	-0.5	
28	Shaim	Mortymya-Tet	P2	140.0	119.8	20.2	
29	Shaim	North Tetere	P1	59.0	116.7	-57.7	
30	Shaim	East Teterev	P2	60.0	72.9	-12.9	
31	Shaim	South Tetere	P1	119.0	119.1	-0.1	
32	Shaim	South Tolums	P1	45.0	61.2	-16.2	
33	Shaim	North Tolums	P1	53.0	80.9	-27.9	
34	Shaim	East Tolumsk	P3	7.3	50.3	-43.0	
35	Shaim	South Potana	P3	46.1	88.7	-42.6	
36	Shaim	North Potana	P3	147.0	74.0	72.9	
37	Shaim	Kartopya-Okh	P3	63.0	71.2	-8.2	
38	Shaim	West Kartopy	P3	40.0	61.1	-21.1	
39	Shaim	Yakhla	Yu3	3.7	2.5	1.1	*
40	Shaim	Yakhla	Yu6-7	61.7	93.3	-31.6	
41	Shaim	Lovinskoye	Yu2	69.0	62.3	6.6	
42	Shaim	Filippovskoy	P2	30.0	70.6	-40.6	
43	Shaim	North Ubinsk	P3	57.0	17.0	39.9	
44	Shaim	West Ubinsko	Yu2	145.0	72.1	72.8	
45	Shaim	Lesser Ubins	P3	47.0	75.4	-28.4	
46	Shaim	South Ubinsk	Yu2	36.0	38.1	-2.1	
47	Shaim	Central Muly	P3	7.5	16.2	-8.7	
48	Shaim	Danilovskoye	P1	204.0	127.4	76.5	

49	Shaim	Lemya	Yu2	12.8	52.8	-40.0
50	Shaim	Upper Lemya	Yu2	4.8	35.2	-30.4

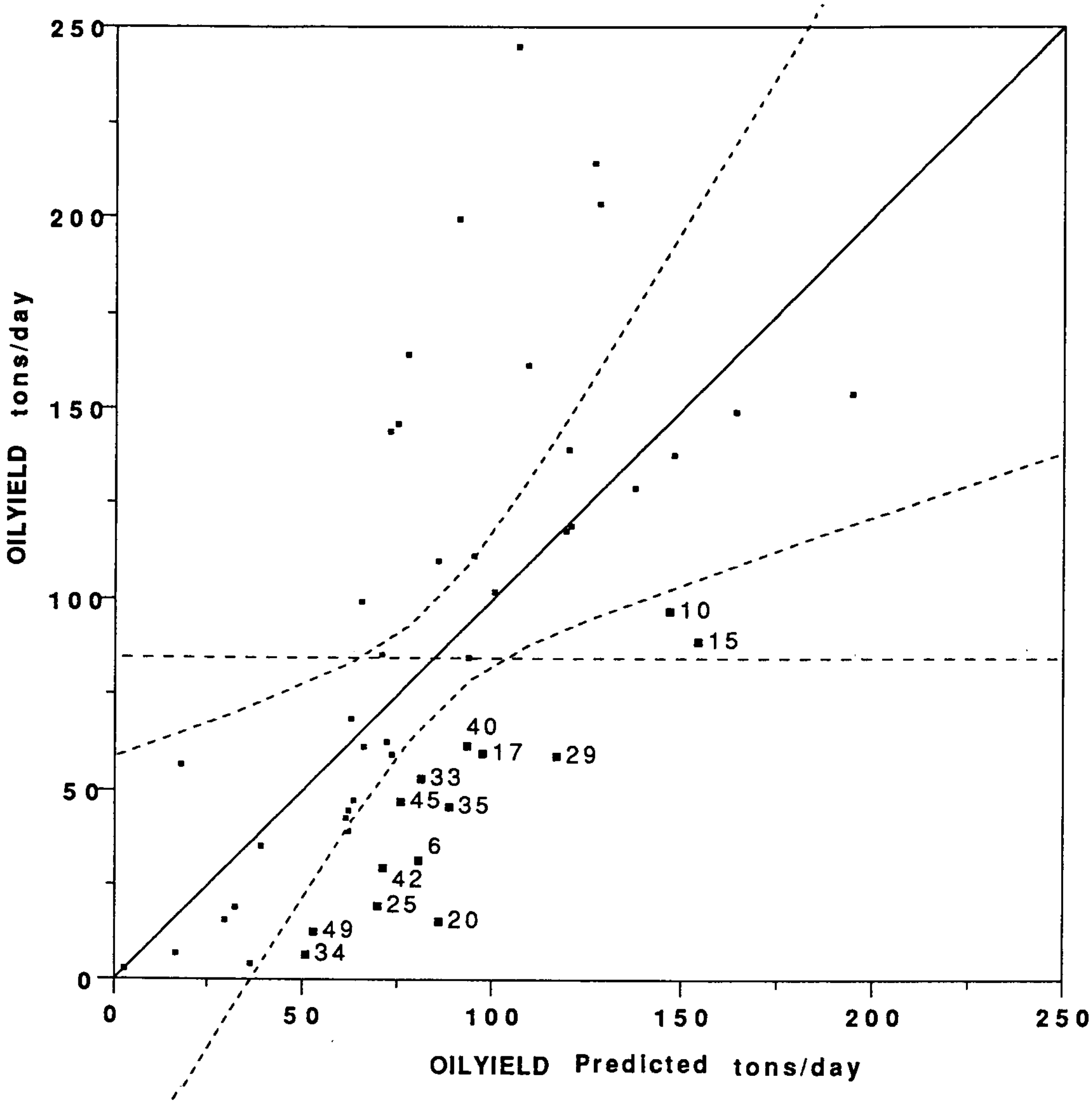
* = large leverage ; ** = outlier - these reservoirs are considered by the regression analysis to be anomalous for prediction purposes.



MULTIDIMENSIONAL SCALING MAP OF OIL RESERVOIRS IN DATA SET 3
The bubble size is scaled so that the radius is proportional to reported oil yield. Reservoirs considered to be outside the normal prediction range by the multiple regression analysis are flagged with *. The reference numbers are keyed to the reservoir names in the listing. The numbers that are underlined signify those reservoirs indicated by regression analysis to be producing less than their potential.

WEST SIBERIA DATA SET 3

Whole model response plot of predicted oil yield versus reported oil yield. The lower dashed curve is the significance limit for reservoirs whose predicted oil yield are significantly greater than their reported yield. These reservoirs are identified in the listing.



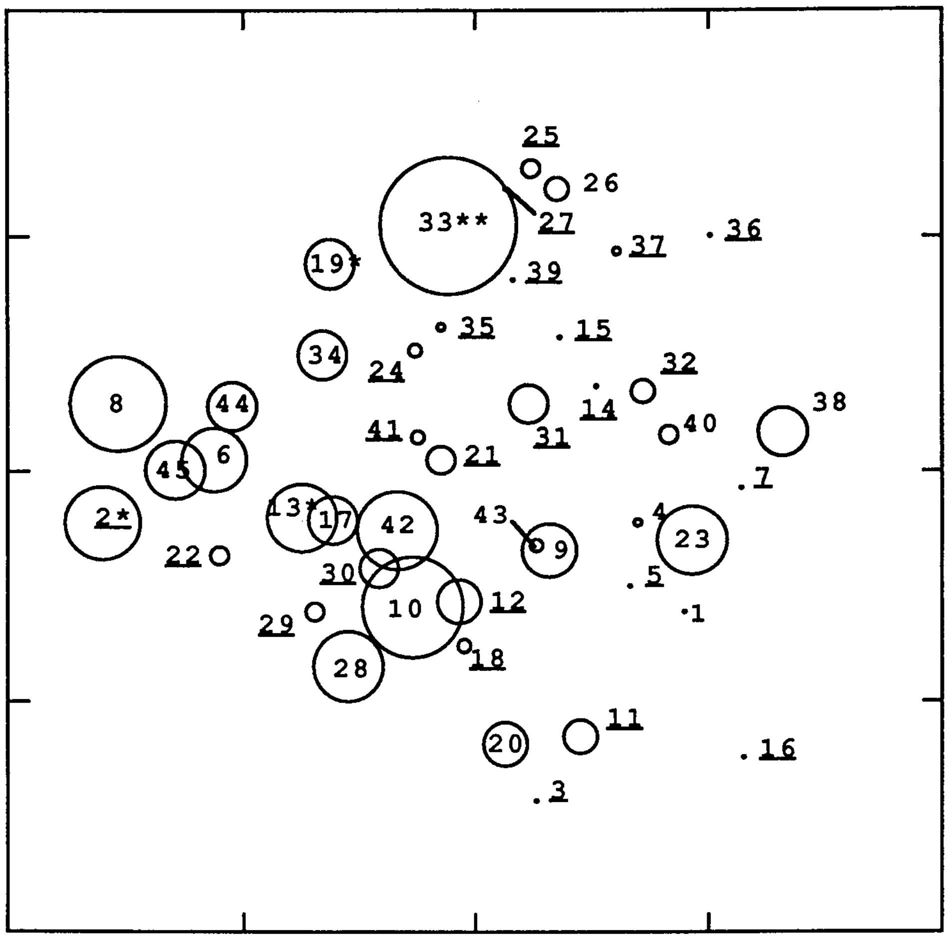
FIELD	RESERVOIR	YIELD	PREDICTION	ID
Tagra	Yu1	32	80.	6
Muravlenkov	BS11	97.5	146.	10
Urengoy	BU10	89	153.	15
Khokhryakovs	Yu1	60	97.	17
Mulymyinskoy	P1	16	85.	20
West Mortymy	P1	20	69.	25
North Tetere	P1	59	116.	29
North Tolum	P1	53	80.	33
East Tolumsk	P3	7.3	50.	34
South Potana	P3	46.1	88.	35
Yakhla	Yu6-7	61.7	93.	40
Filippovskoy	P2	30	70.	42
Lesser Ubins"	P3	47	75.	45
Lemya	Yu2	12.8	52.	49

WEST SIBERIA DATA SET 4

(KRASNOLENINSKIY NGR,NIZHNEVARTOVSK NGR, ALEKSANDROVSKIY NGR, VASYUGAN NGR, PUDINSKIY NGR, KAYMYSOVSKIY NGR,MEZHOVSKIY NGR, SILGA NGR, AND PAYDUGA NGR)

ID	NGR	FIELD/RES.	AGE	OILYIELD	PRED.	RESID.	
1	Krasnol	Kamennoye	PK21	12.0	9.3	2.6	
2	Krasnol	Kamennoye	Yu1-1	150.0	189.4	-39.4	*
3	Krasnol	Yelizarovsk	Yu1	4.9	60.5	-55.6	
4	Krasnol	Lorba	PK2	20.0	14.4	5.5	
5	Krasnol	Yemyegovsko	PK21	8.5	20.3	-11.8	
6	Krasnol	Yemyegovsko	Yu2	130.0	120.9	9.0	
7	Krasnol	Palyanovsko	PK2	4.3	6.1	-1.8	
8	Krasnol	Palyanovsko	Yu2	192.0	102.9	89.0	
9	Nizhnev	Sovetskoye	B6	111.0	70.1	40.8	
10	Nizhnev	Sovetskoye	B10	195.0	102.0	92.9	
11	Nizhnev	Sovetskoye	Yu1-1	72.0	112.7	-40.7	
12	Nizhnev	Strezhevoye	Yu1-1	96.0	103.3	-7.3	
13	Nizhnev	Malorechens	Yu1-2	140.0	102.4	37.5	*
14	Nizhnev	Matyushka	Yu1-1	13.0	77.3	-64.3	
15	Aleksan	Nikolskoye	Yu1-1	6.8	53.7	-46.9	
16	Aleksan	Severnoye	B7	18.0	44.1	-26.1	
17	Aleksan	Severnoye	B9	98.4	72.2	26.1	
18	Aleksan	Severnoye	B12	30.7	63.2	-32.5	
19	Aleksan	Vartovskoye	Yu6	103.0	99.4	3.5	*
20	Vasyuga	Central Nyur	Yu1-1	91.5	89.5	1.9	
21	Vasyuga	Klyuchevsk	Yu1-1	63.4	68.3	-4.9	
22	Vasyuga	Upper Salat	Yu1-1	43.5	118.1	-74.6	
23	Vasyuga	South Chere	A10	141.0	62.5	78.4	
24	Vasyuga	Shinginskoy	Yu1-1	28.9	73.3	-44.4	
25	Vasyuga	Chkalovskoy	Yu1-1	39.4	52.9	-13.5	
26	Pudinsk	West Ostani	Yu1-1	50.6	32.3	18.2	
27	Pudinsk	Selimkhanov	Yu1-3	6.0	45.7	-39.7	
28	Kaymyso	Olenye	Yu1-1	144.0	122.0	21.9	
29	Kaymyso	Katylga	Yu1-1	39.5	102.5	-63.0	
30	Kaymyso	Pervomaysko	Yu1-1	86.0	99.7	-13.7	
31	Mezhovs	Igolskoye	Yu1-1	81.0	93.2	-12.2	
32	Mezhovs	Talovoye	Yu1-1	56.0	70.8	-14.8	
33	Mezhovs	South Tabag	M	266.0	100.3	165.6	**
34	Mezhovs	Kalinovoye	Yu1-1	105.0	88.1	16.8	
35	Mezhovs	Lower Tabag	Yu3	21.6	75.7	-54.1	
36	Mezhovs	Poselkovoye	Yu1-3	18.9	41.0	-22.1	
37	Mezhovs	Karayskoye	Yu1-0	26.0	67.7	-41.7	
38	Silga	Sobolinoye	B6	103.2	30.0	73.1	
39	Payduga	Kievyegansk	Yu1-1	14.0	71.9	-57.9	
40	Payduga	Lineynoye	Yu1-1	42.0	17.8	24.1	
41	Mezhovs	East Mezhov	Yu1-1	34.0	84.8	-50.8	
42	Mezhovs	Verkh-Tarsk	Yu1-1	160.6	86.8	73.7	
43	Mezhovs	Rakitinskoy	Yu1	32.0	24.9	7.0	
44	Mezhovs	Maloichskoy	M3	100.0	74.6	25.3	
45	Mezhovs	Maloichskoy	M11	121.2	99.8	21.3	

* = large leverage ; ** = outlier - these reservoirs are considered by the regression analysis to be anomalous for prediction purposes.

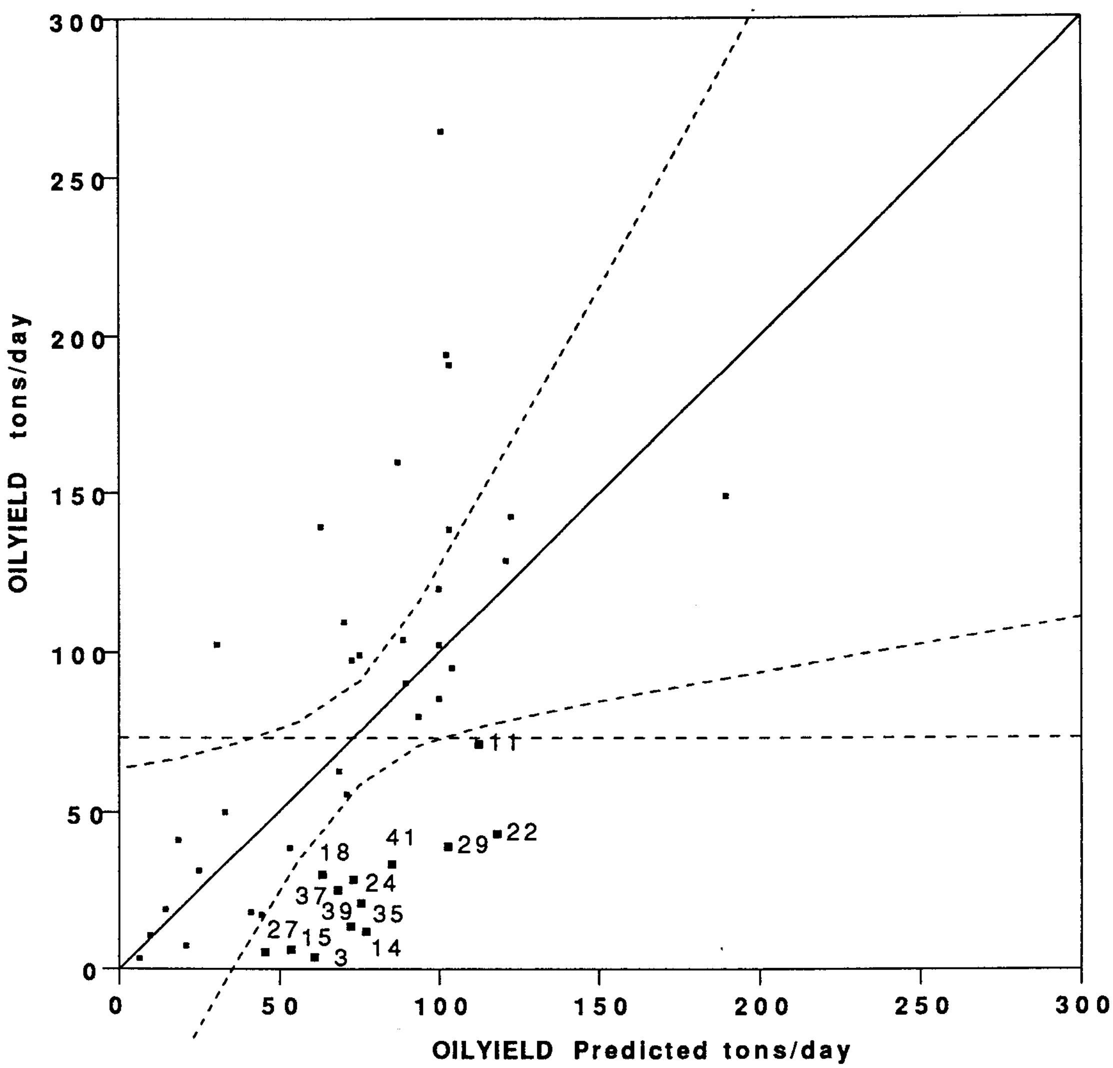


MULTIDIMENSIONAL SCALING MAP OF OIL RESERVOIRS IN DATA SET 4

The bubble size is scaled so that the radius is proportional to reported oil yield. Reservoirs considered to be outside the normal prediction range by the multiple regression analysis are flagged with *. The reference numbers are keyed to the reservoir names in the listing. The numbers that are underlined signify those reservoirs indicated by regression analysis to be producing less than their potential.

WEST SIBERIA DATA SET 4

Whole model response plot of predicted oil yield versus reported oil yield. The lower dashed curve is the significance limit for reservoirs whose predicted oil yield are significantly greater than their reported yield. These reservoirs are identified in the listing.



FIELD	RESERVOIR	YIELD	PREDICTION	ID
Yelizarovsk	Yu1	4.9	60.	3
Sovetskoye	Yu1-1	72	112.	11
Matyushka	Yu1-1	13	77.	14
Nikolskoye	Yu1-1	6.8	53.	15
Severnoye	B12	30.7	63.	18
Upper Salats	Yu1-1	43.5	118.	22
Shinginskoye	Yu1-1	28.9	73.	24
Selimkhanov	Yu1-3	6	45.	27
Katylga	Yu1-1	39.5	102.	29
Lower Tabaga	Yu3	21.6	75.	35
Karayskoye	Yu1-0	26	67.	37
Kievyegansko	Yu1-1	14	71.	39
East Mezhovs	Yu1-1	34	84.	41

*FINAL COPY

Regression models of oil production

Productivity of petroleum reservoirs is related to numerous factors, many of which may be unique to individual oil accumulations. However, certain geological properties have a logically consistent relation to production, and can be used to assess reservoir yield. Among these are the basic constituents of volume, which are the reservoir height, area of closure, and porosity. From these, the amount of void space which potentially could be filled with oil can be calculated. If, in addition, the initial oil saturation and gas/oil ratio are known, the proportion of void space that is filled with oil can be determined and the volume of initial oil in place estimated.

Producibility is an expression of the amount of oil that can be recovered from a reservoir as a function of time and reflects not only the volume of oil in place, but also the physical characteristics of the reservoir fluids and rocks, as well as the environment of the reservoir. Permeability is a response of the nature of the network of pores that contain the oil and other reservoir fluids. Temperature and pressure, both related to depth of burial, alter the viscosities of the fluids and hence the rate at which they can be extracted from the pore network. A reservoir may contain a large volume of initial oil in place but may have produced only a small amount of oil if the factors affecting productivity are adverse or if the reservoir has been damaged by poor production techniques. Our studies are designed to indicate those reservoirs which seem, from the available data, to be under–productive for whatever reason.

Unfortunately, not all of the critical properties of reservoirs needed to perform such an analysis are contained in the available data. A critical property is simply some measure of lateral reservoir extent, such as reservoir area in square kilometers or hectares. Without such a measure, or a surrogate such as the number of production wells (assuming a more-or-less consistent development well spacing), gross reservoir volume cannot be estimated. However, there is a weak, positive correlation between the height of an oil pool and the area it covers, so measures of reservoir height or thickness also reflect area and hence volume. Other important variables are in the data base, but none are complete. Some variables are partially redundant, such as roof depth and absolute height, and others are deterministically correlated, such as depth, pressure, and temperature. These relationships are apparent in scatter plots and matrices of correlations between the variables. It is fortunate that such redundancies exist between the variables, because the data are incomplete for most reservoirs and this allows us to pick and choose among the variables to obtain the most complete suite of reservoirs for each analysis. Because it is necessary to use a slightly different set of variables for each analysis, direct comparisons between regions are not possible. Each analysis should be regarded as relative assessments of the reservoirs within that set, and not as expressions of absolute volumes of unrealized production.

The composition of the reservoir host rock greatly influences the pore structure and fluid flow characteristics in a complex manner that may not be reflected in average porosities and permeabilities. Following standard industry practice, we have analyzed reservoir properties separately for the major reservoir lithologies identified in the database (sandstone, limestone, and reef rock). It also is common practice to distinguish reservoirs on the basis of drive mechanism (gas cap, solution gas, water drive, etc.), but the necessary information is not given in the data tables.

Two forms of statistical assessment have been made. The first is a more conventional multiple regression of oil yield on reservoir properties, which embodies the assumption of a linear relationship between reservoir properties and yield. (Experience elsewhere suggests this assumption is somewhat suspect; because the distribution of field volumes is highly skewed, volume may increase in a greater–than–proportional manner within the largest field size classes. This possibility can be examined by using the logarithm of oil yield as the dependent variable.)

In a conventional application, using a large number of predictor (independent) variables in the regression equation results in better predictions. However, the statistical significance of a regression based on many variables may be no greater, or even less, than the significance of a simpler model. This is because more degrees freedom are required for a model as the number of parameters to be estimated is increased. This effect is exaggerated if values are missing in the data, because fewer reservoirs will have all of the necessary measurements needed for a complicated model. Consequently, selecting an appropriate regression model is a trial-and-error process, balancing the better predictions produced by a larger model against the greater sample size available if a smaller model is used. For this reason, the regression model differs from one data set to another.

Tables 1–4 list the number of available observations for each variable, among the major lithologies in each region. Note that some variables have large numbers of missing observations, which restricts their use in regression analysis. Table 5 gives the final regression models for each reservoir lithology in each region (for those that could be analyzed by regression) and the goodness-of-fit. Most of the regressions include one variable correlated with reservoir thickness and/or another variable correlated with depth of burial, and porosity. All of the reported regressions would be statistically significant at the 95% level if all assumptions necessary for regression were met. Because of sampling deficiencies and the sequential nature of the analyses, the true levels of significance are much lower. However, since the significance levels are used only in a relative manner for selecting variables in the prediction equation, this is of limited consequence.

Only two reservoir lithologies, 8–limestone and 11–sandstone, occur with sufficient frequency for analysis in all regions. In addition, there are sufficient observations of lithology 13–reef rock, for analysis in the Ufa–Orenberg region. Other lithologies occur rarely and are not included in the analyses.

The Caspian Region differs significantly from all other regions studied. Although the distributions of the reservoir properties appear similar to distributions from other regions, and interrelations between variables seem to follow patterns observed elsewhere, it was not possible to find a linear combination of any of the reservoir properties that would provide an estimate of oil yield. There are several possible explanations for this failure. Perhaps the records of oil yield are inconsistent for fields in the Caspian Region because of political, organizational, or other causes. Production may vary widely because of differences in crude oil composition—crudes from fields in the Caspian Region vary from heavy asphaltic oils with poor flow characteristics, to light paraffinitic and heavily gas-cut crudes. Some of the fields may have significant gas caps or condensate volumes, which reduce the contained amount of oil without a commensurate reduction in measures of thickness or porosity. Finally, geological conditions in the Caspian Region are highly diverse and fields are localized by a great variety of trapping mechanisms, including diaperic salt movements which can produce extreme structural configurations. Any or all of these circumstances may result in a heterogeneous mixture of populations of oil field types that, when combined, show no consistent relationships between field properties and field yield. Because of the limited data, it is not possible to subdivide Caspian Region fields into more homogeneous subsets that might be responsive to regression-type forecasting.

Figures 1 through 7 show the results of regression analysis for the Ufa-Orenberg, Lower Volga, and Timan–Pechora Regions, each subdivided according to dominant reservoir lithology. Reservoir units whose characteristics indicate they are underproductive are identified on the figures or by number in the figure captions. The figures contrast the actual oil production versus that predicted by the regression model; the straight line is a plot of the model response which should be compared to the actual production, either above or below the predicted value. Our interest is on those reservoir units whose actual production falls significantly below the level predicted, as indicated by the dashed lower significance level curve. Many circumstances may cause a reservoir unit to fall into this area: actual production may be incorrectly reported; geologic factors not considered by the regression equation may be inhibiting production; other fluids (water, gas, condensate) may occupy part of the reservoir; mechanical, formational, or completion problems may be restricting production; or the interval may be inadequately exploited. The reason(s) why a specific reservoir unit fails to produce as expected cannot be deduced from this analysis; rather, it is a way of indicating those reservoir units which merit further investigation. The regression model flags those reservoirs that may be most amenable for enhancing production, but does not predict the amount of oil that might be produced.

Multidimensional Scaling Models of Oil Production

In a second approach to analysis of the reservoir data, multidimensional scaling was applied to map apparent similarity of individual reservoirs based on their geological characteristics keyed to production. As with the more conventional statistical procedure of regression analysis, the information content of the database has the significant limitation that no measures of areal dimension were available. Each plot is a conceptual "map" of the reservoirs, where proximity is a representation of overall similarity. The closest fields are most similar; the fields that are farthest apart are most dissimilar. The distances between the reservoirs were computed such that their order is the best possible two-dimensional representation of the order of similarity measures between them. The similarities were computed as a weighted composite of the variables that were most effective in the prediction of total oil yield. The weighting coefficients were Spearman rank correlation coefficients between those variables and oil yield. By this means the mapping was supervised by predicating similarity of reservoirs to geological characteristics most strongly tied to oil production. The monotonic criterion of rank ordering used throughout also ensures that the method is general and has no assumptions of linearity or other numerical functions.

The multidimensional scaling plots are shown in Figures 8 through 12 and match the limestone and sandstone subsets used for the regression analysis. No plots were produced for the Caspian Region because the low rank correlation coefficients between oil yield and geological variables showed that these plots would have little meaning. Although regression analyses were made for reef reservoirs in the Ufa-Orensburg Region and limestone reservoirs in the Lower Volga Region, the number of reservoirs and their order statistics in these two cases was insufficient for effective multidimensional scaling..

The size of a bubble in the figures reflects the total oil yield of the reservoir plotted at each coordinate location. The table of reservoirs with each plot have identifications keyed to the index number in each bubble. The potential for increased production is suggested for those reservoirs that are significantly smaller than neighboring reservoirs. The analysis indicates that they have a similar mix of geological characteristics that appear to be linked with production. The plots should be regarded as a reconnaissance device to flag reservoirs that have potential for increased production. They should be considered in coordination with the results of the regression analysis. Most importantly, conclusions must be tempered by the additional consideration of areal size. Smaller reservoirs would be expected to have lower total oil yields. Hopefully, at least some indication of reservoir area has been captured through implicit correlations with vertical measures of size.

Table 1. Statistics on reservoir units in the Ufa-Orenburg Region.

Number of reservoirs	
in data set	190
complete data sets	110
limestone reservoirs	29
sandstone reservoirs	64
reef reservoirs	17
Measurements in limestone reservoirs	
Trap height	21
Roof depth	25
Thickness	27
Absolute height	22
Reservoir height	21
Porosity	24
Permeability	23
Pressure	23
Temperature	14
Gas/oil ratio	23
Measurements in sandstone reservoirs	
Trap height	55
Roof depth	57
Thickness	54
Absolute height	54
Reservoir height	55
Porosity	65
Permeability	64
Pressure	60
Temperature	35
Gas/oil ratio	64
Measurements in reef reservoirs	
Trap height	16
Roof depth	17
Thickness	16
Absolute height	16
Reservoir height	16
Porosity	16
Permeability	16
Pressure	17
Temperature	15
Gas/oil ratio	17

Table 2. Statistics on reservoir units in the Lower Volga Region.

Number of reservoirs	
in data set	82
complete data sets	82
limestone reservoirs	14
sandstone reservoirs	67
reef reservoirs	1
Measurements in limestone reservoirs	
Trap height	13
Roof depth	14
Thickness	14
Absolute height	14
Reservoir height	14
Porosity	13
Permeability	11
Pressure	13
Temperature	14
Gas/oil ratio	10
Measurements in sandstone reservoirs	
Trap height	59
Roof depth	66
Thickness	52
Absolute height	60
Reservoir height	62
Porosity	57
Permeability	51
Pressure	57
Temperature	58
Gas/oil ratio	52
Measurements in reef reservoirs	
Trap height	1
Roof depth	1
Thickness	1
Absolute height	1
Reservoir height	1
Porosity	1
Permeability	1
Pressure	1
Temperature	1
Gas/oil ratio	1

Table 3. Statistics on reservoir units in the Caspian Region.

Number of reservoirs	
in data set	149
complete data sets	133
limestone reservoirs	6
sandstone reservoirs	119
reef reservoirs	8
Measurements in limestone reservoirs	
Trap height	1
Roof depth	6
Thickness	6
Absolute height	6
Reservoir height	6
Porosity	6
Permeability	2
Pressure	4
Temperature	3
Gas/oil ratio	2
Measurements in sandstone reservoirs	
Trap height	3
Roof depth	116
Thickness	114
Absolute height	115
Reservoir height	106
Porosity	116
Permeability	75
Pressure	87
Temperature	40
Gas/oil ratio	81
Measurements in reef reservoirs	
Trap height	4
Roof depth	8
Thickness	4
Absolute height	7
Reservoir height	7
Porosity	8
Permeability	1
Pressure	8
Temperature	3
Gas/oil ratio	4

Table 4. Statistics on reservoir units in the Timan-Pechora Region.

Number of reservoirs	
in data set	127
complete data sets	127
limestone reservoirs	55
sandstone reservoirs	66
reef reservoirs	5
Measurements in limestone reservoirs	
Trap height	44
Roof depth	54
Thickness	40
Absolute height	51
Reservoir height	51
Porosity	53
Permeability	28
Pressure	39
Temperature	35
Gas/oil ratio	33
Measurements in sandstone reservoirs	
Trap height	53
Roof depth	64
Thickness	60
Absolute height	59
Reservoir height	56
Porosity	66
Permeability	43
Pressure	59
Temperature	56
Gas/oil ratio	53
Measurements in reef reservoirs	
Trap height	3
Roof depth	5
Thickness	3
Absolute height	4
Reservoir height	4
Porosity	5
Permeability	2
Pressure	3
Temperature	3
Gas/oil ratio	3

Table 5—Regression equations for oil yield in former Soviet petroleum-producing regions. Data have been separated according to dominant reservoir lithology.

Ufa-Orenberg Region

Lithology 8–limestone

$Oil\ Yield = 67.189 - 0.088 \cdot Roof\ Depth + 6.379 \cdot Pressure$

R = 0.48

Lithology 11–sandstone

$Oil\ Yield = -122.079 + 3.856 \cdot Reservoir\ Height + 9.366 \cdot Porosity$

R = 0.70

Lithology 13–reef rock

$Oil\ Yield = 277.800 - 0.310 \cdot Roof\ Depth + 3.698 \cdot Porosity + 16708 \cdot Pressure$

R = 0.71

Lower Volga Region

Lithology 8–limestone

$Oil\ Yield = 2.452 - 0.028 \cdot Reservoir\ Height - 0.382 \cdot \log Permeability$

R = 0.91

Lithology 11–sandstone

$Oil\ Yield = -42.672 + 0.767 \cdot Reservoir\ Thickness + 3.527 \cdot Porosity$

R = 0.64

Caspian Region

Lithology 8–limestone

No significant regression could be found

Lithology 11–sandstone

No significant regression could be found

Timan–Pechora Region

Lithology 8–limestone

$Oil\ Yield = 10^{0.0040 + 0.0004 \cdot Roof\ Depth + 0.0531 \cdot Porosity}$

Equivalent to:

$\log Oil\ Yield = 0.0040 + 0.0004 \cdot Roof\ Depth + 0.0531 \cdot Porosity$

R = 0.42

Lithology 11–sandstone

$$Oil\ Yield = -131.094 + 0.187 \cdot Trap\ Height - 0.063 \cdot Roof\ Depth + 4.549 \cdot Temperature - 0.227 \cdot G/O\ Ratio + 48.618 \cdot \log Permeability$$

R = 0.59

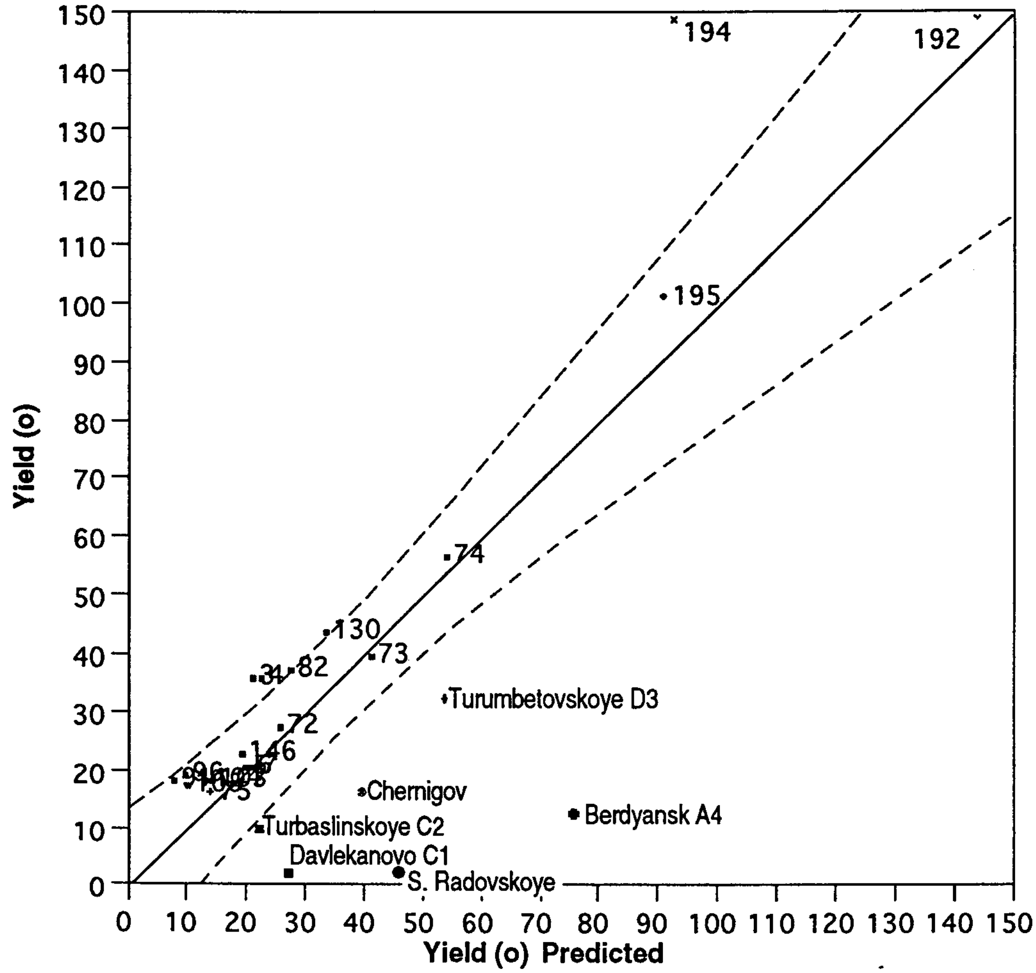


Figure 1. Predicted versus actual oil production for limestone reservoirs in the Ufa-Orensburg region. Numbers refer to sequence in data base. Named reservoirs are significantly under-productive according to regression model. Dashed lines are approximate 95% confidence limits on model.

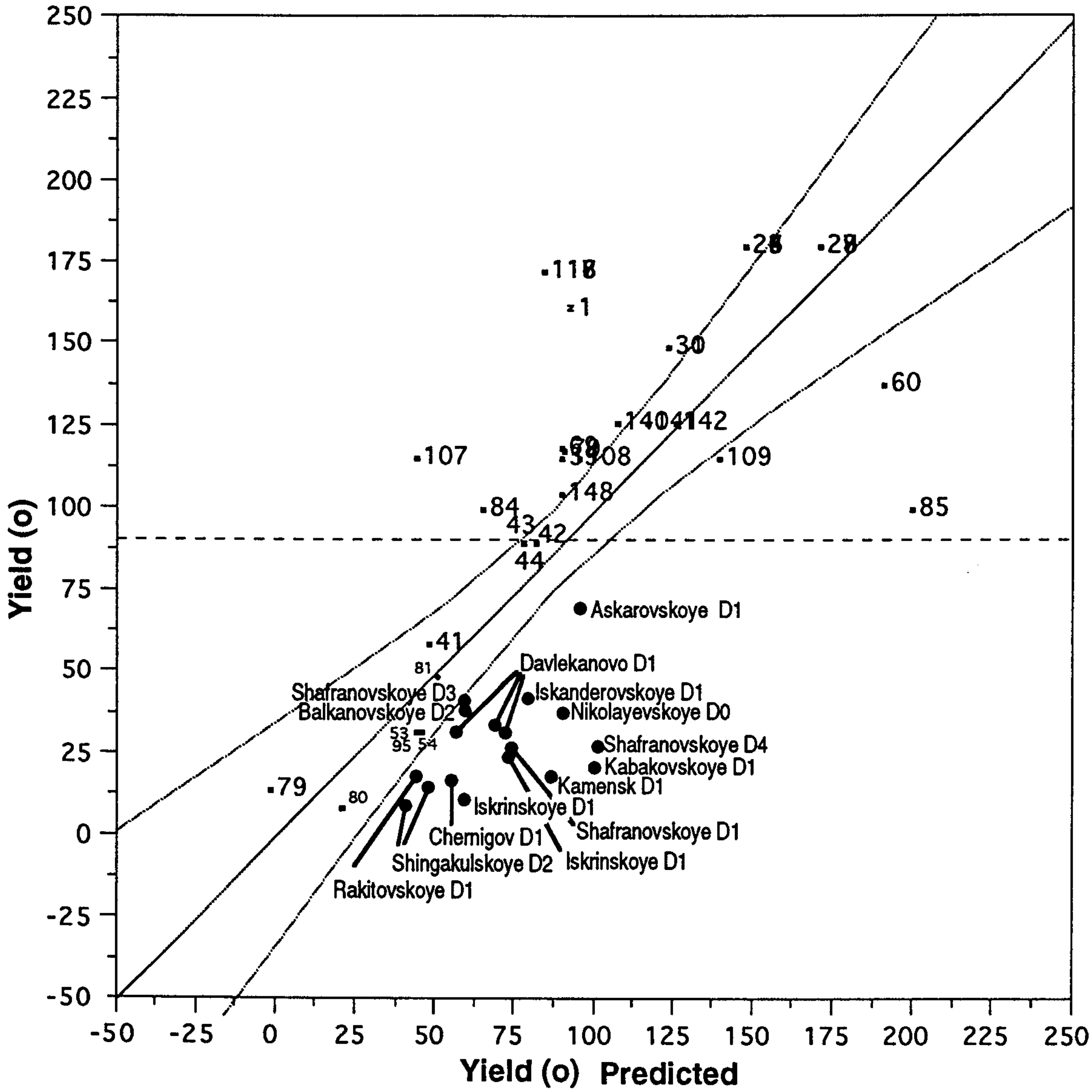


Figure 2. Predicted versus actual oil production for sandstone reservoirs in the Ufa-Orensburg region. Numbers refer to sequence in data base. Named reservoirs are significantly under-productive according to regression model. Dashed lines are approximate 95% confidence limits on model.

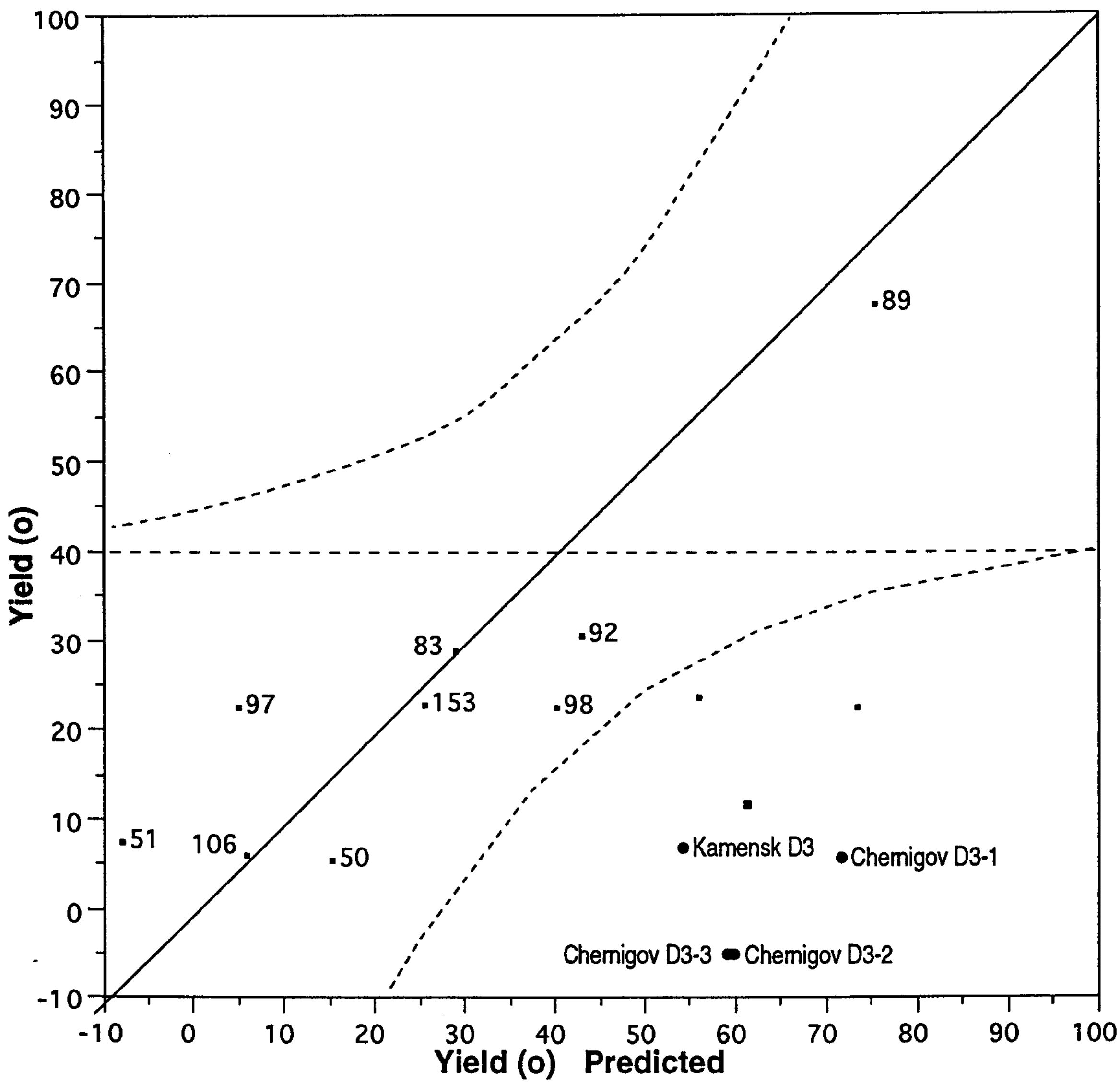


Figure 3. Predicted versus actual oil production for reef rock reservoirs in the Ufa-Orensburg region. Numbers refer to sequence in data base. Named reservoirs are significantly under-productive according to regression model. Dashed lines are approximate 95% confidence limits on model.

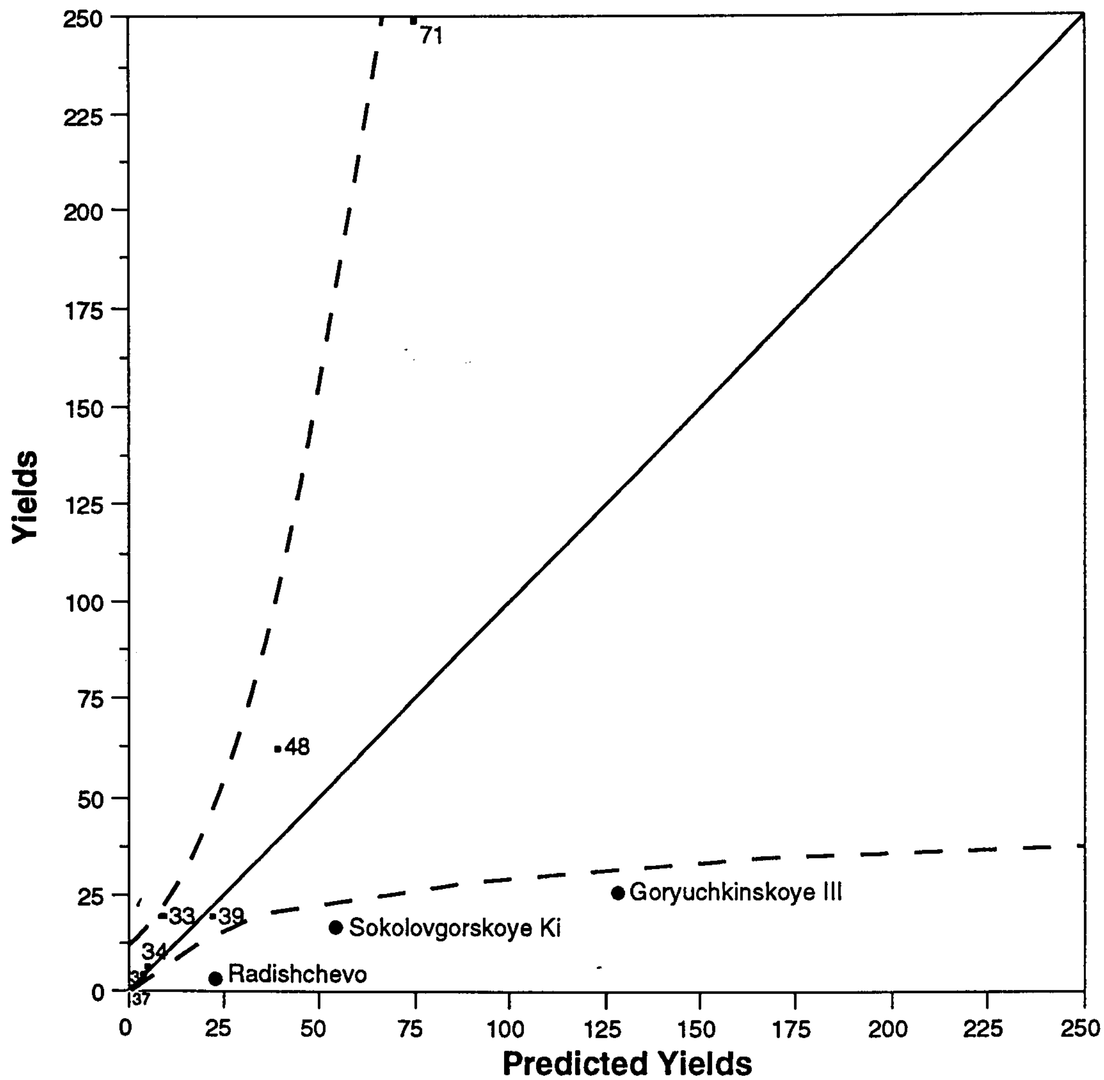


Figure 4. Predicted versus actual oil production for limestone reservoirs in the Lower Volga region. Numbers refer to sequence in the data base. Named reservoirs are significantly under-productive according to regression model. Dashed lines are approximate 95% confidence limits on model.

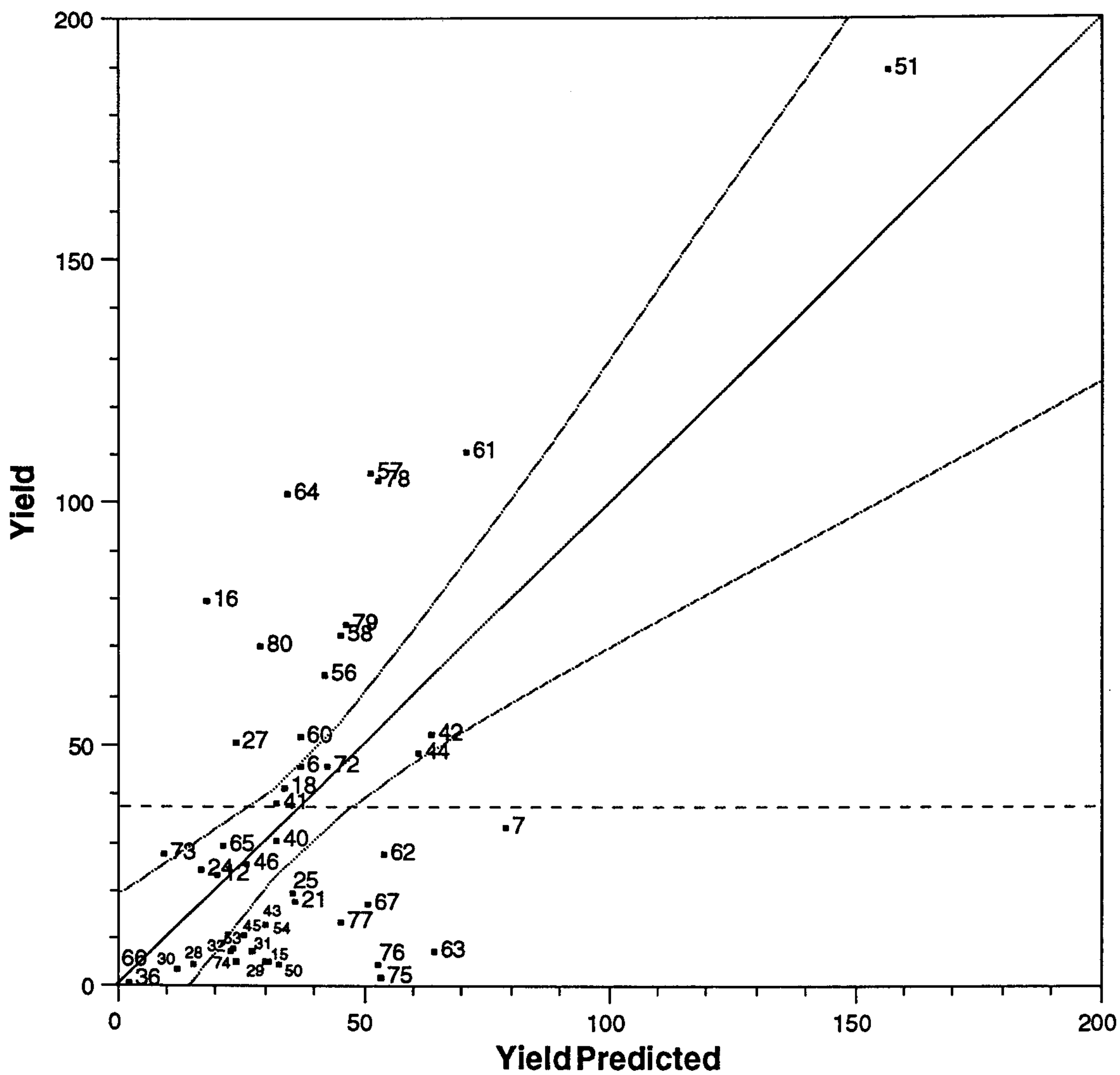


Figure 5. Predicted versus actual oil production for sandstone reservoirs in the Lower Volga region. Numbers refer to sequence in the data base. Reservoirs significantly under-productive according to regression model are listed by number in accompanying list. Dashed lines are approximate 95% confidence limits on model.

Figure 5. Lower Volga sandstone oil reservoirs that seem to be underproductive, listed in order of largest predicted oil yield to smallest.

7	Splavnushskoye	D2
63	Gryazushinskoye	D2
62	Pionerskoye	
75	Staritsa	Bob.
76	Fumanovskiy	IX
67	S. Generalskoye	Bob.
77	Fumanovskiy	Bob.
21	Aleksandrovskoye	D2
25	Peschano-Umet	Bob.
50	Solokovgorskoye	D3
15	Goryuchkinskoye	V
29	Atamanovka	D3
54	Solokovgorskoye	D2
43	Guselskoye	D2
31	Yazykovo	V
45	Trofimovskoye	D2
53	Solokovgorskoye	D2
74	Staritsa	X
32	Yazykovo	Bob.

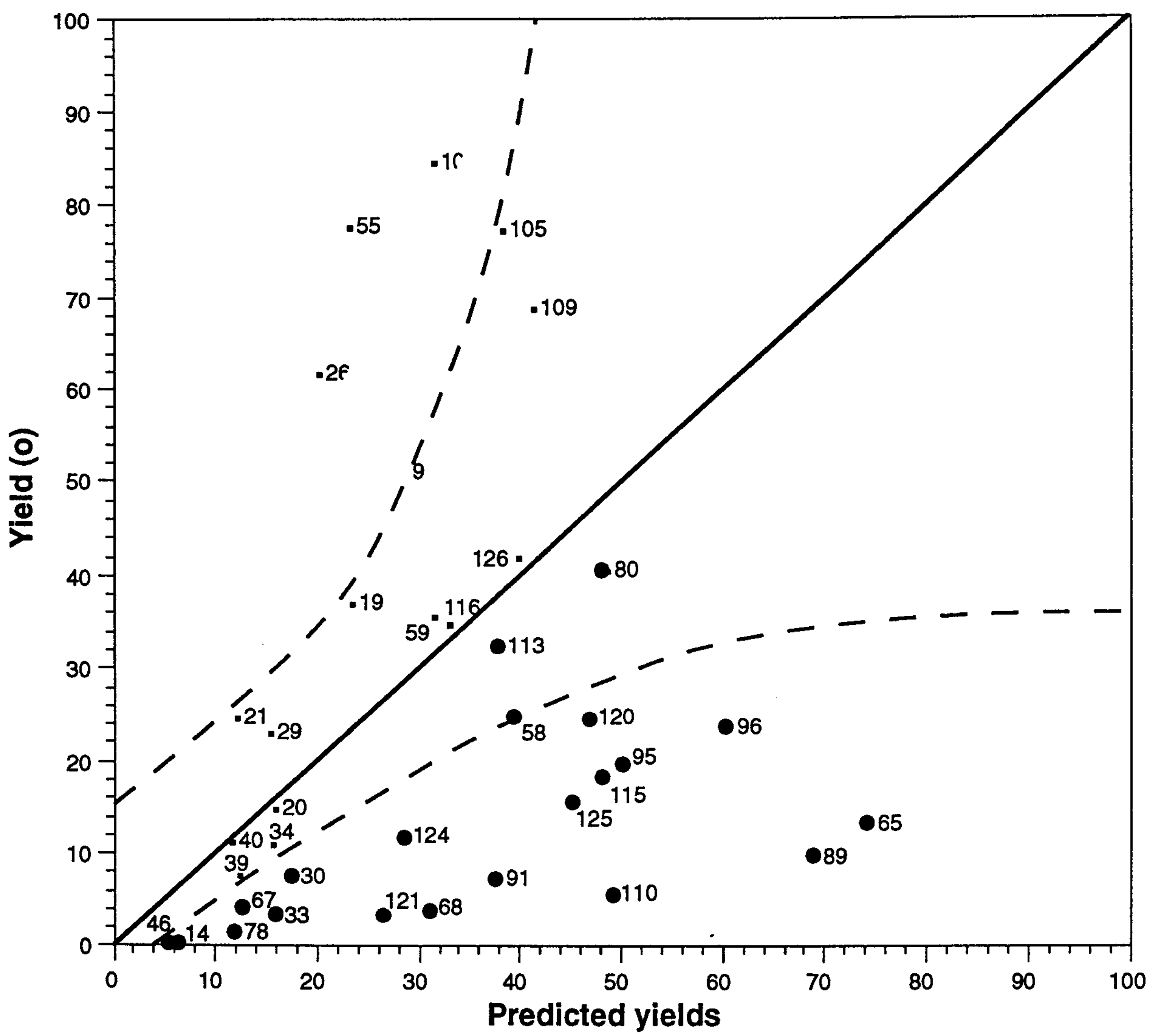


Figure 6. Predicted versus actual oil production for limestone reservoirs in the Timan-Pechora region. Numbers refer to sequence in data base. Reservoirs signicantly under-productive according to regression model are listed by number in the accompanying list. Dashed lines are approximate 95% confidence limits on model.

Figure 6. Timan-Pechora limestone oil reservoirs that seem to be under-productive, listed in order of largest predicted oil yield to smallest.

65	Vozeyskoe	P2
89	N. Kharyaginskoye	
96	Pashorskoye	
95	Khylchuyuskoye	I
110	S. Toraveyskoye	
115	Naulskoye	
120	N. Saremboyskoye	
125	C. Makarikha	
58	Usinsk	
91	Yareyyuskoye	
68	Vozeyskoe	F1
124	C. Makarikha	
121	Nyadeyyuskoye	
30	Luzskoye	Fr1
33	N. Saremboyskoye	
67	Vozeyskoe	F2
78	Vozeyskoe	II
14	Dzherskoye	IV
46	Yugidskoye	K

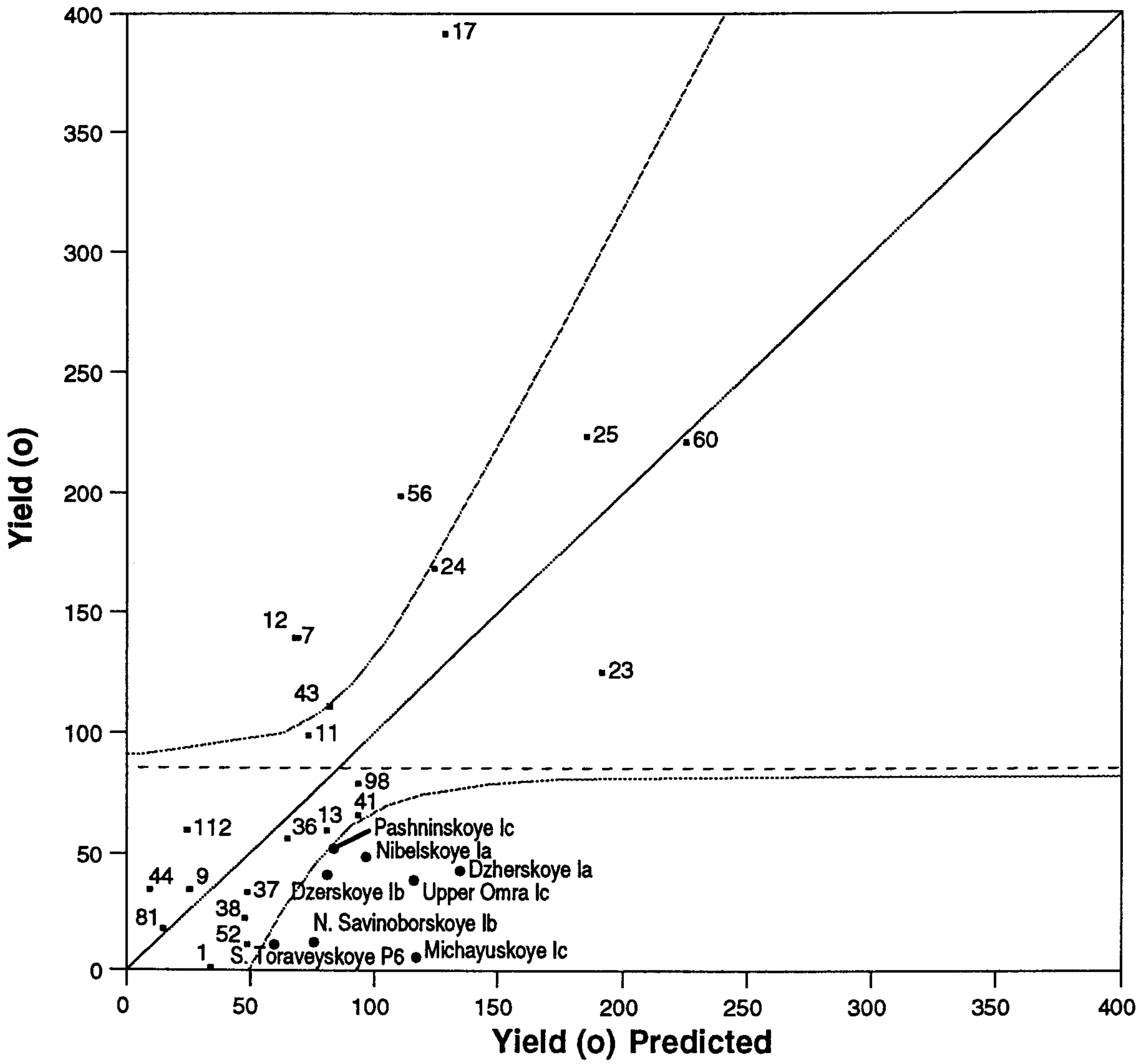
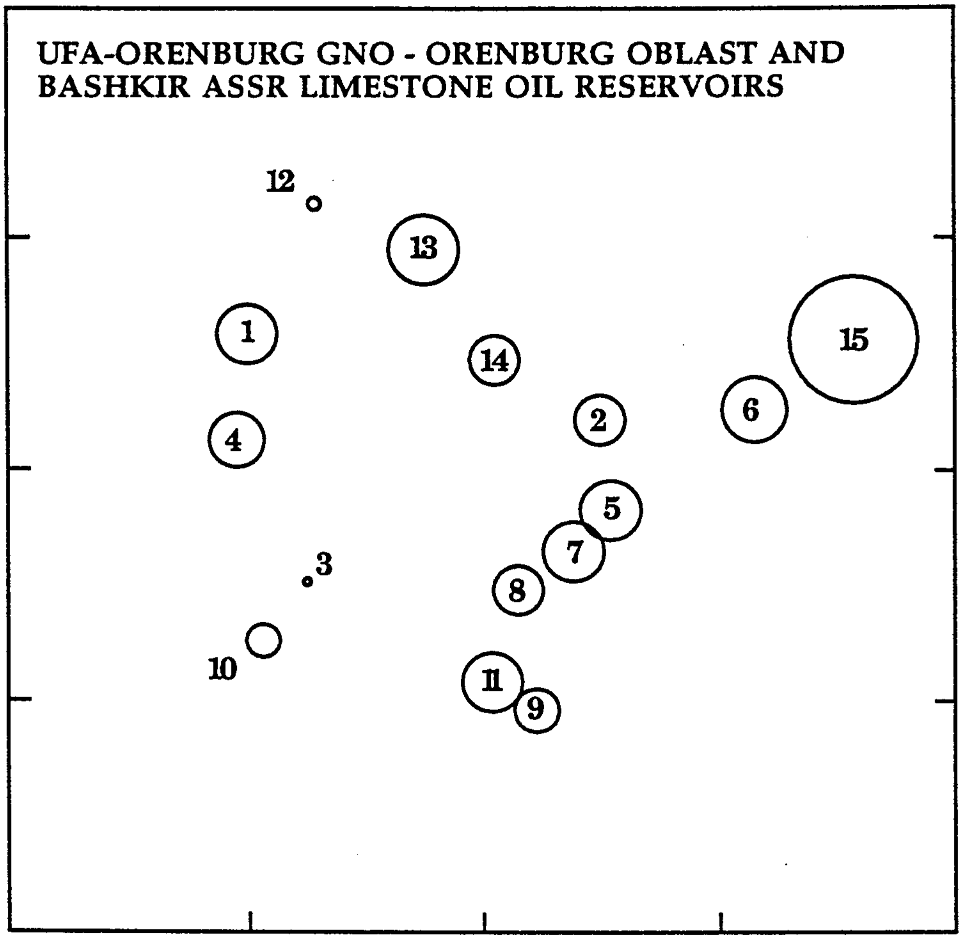
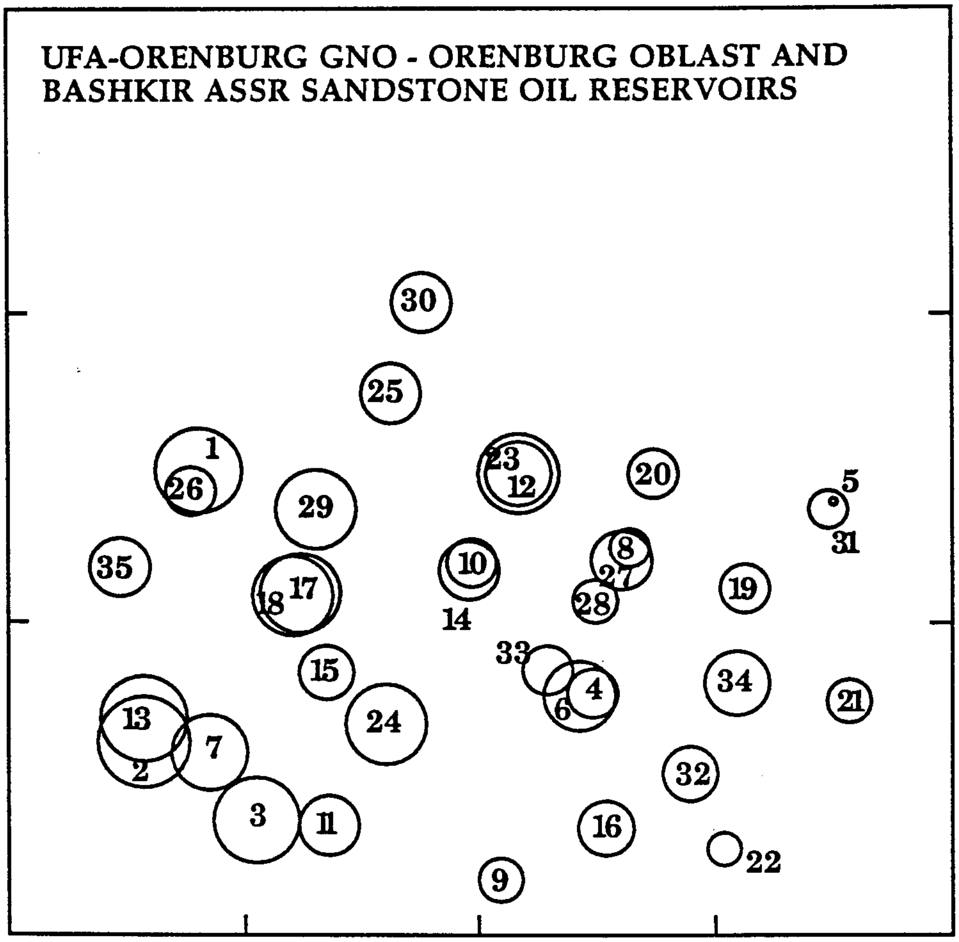


Figure 7. Predicted versus actual oil production for sandstone reservoirs in the Timan-Pechora region. Numbers refer to sequence in data base. Named reservoirs are significantly under-productive according to regression model. Dashed lines are approximate 95% confidence limits on model.



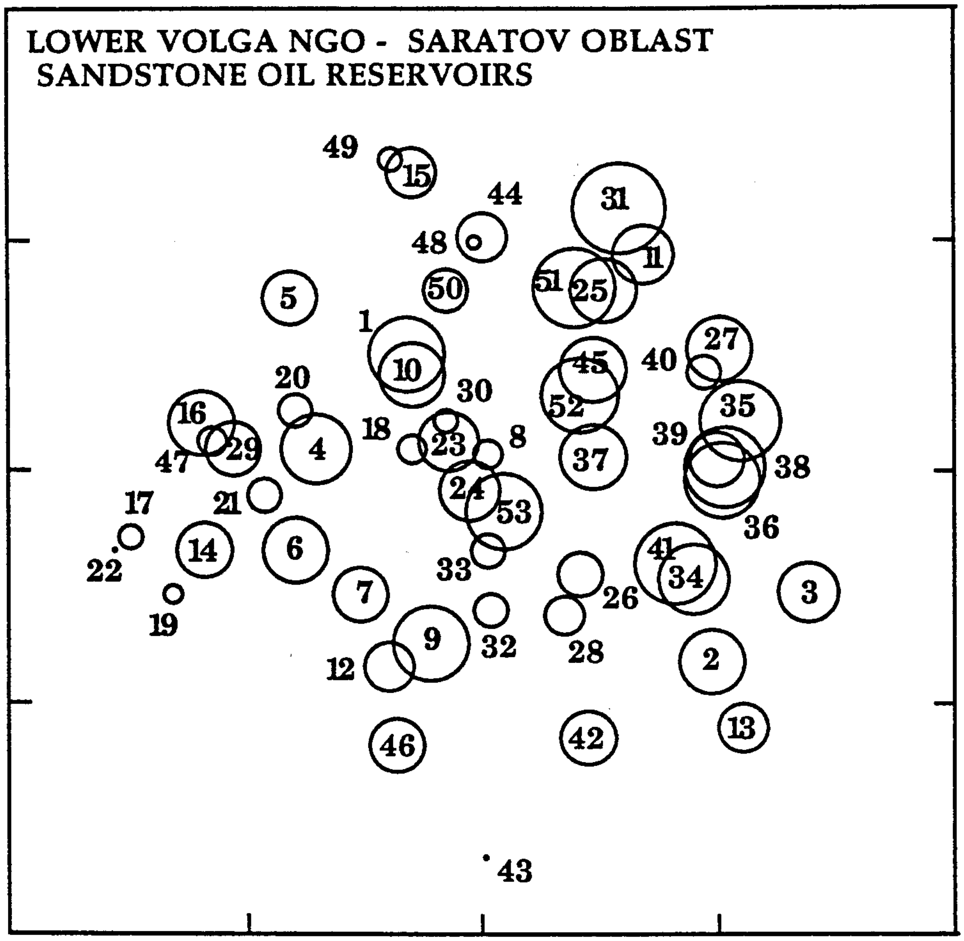
ID	FIELD	RESERVOIR AGE		OYIELD (t per day)
1	Sergeyevskoy	Kizelian	C1ks1	36.0
2	Sergeyevskoy	Cherepetian	C1crp	21.0
3	Davlekanovo	Kizelian	C1ks1	2.4
4	Gordeyevskoy	Kizelian	C1ks1	28.0
5	Gordeyevskoy	Kizelian	C1ks1	40.0
6	Gordeyevskoy	Kizelian	C1ks1	57.0
7	Balkanovskoy	Kizelian	C1ks1	37.7
8	Chernigov	Kizelian	C1ks1	19.4
9	Orlovskoye	Transvolgian	C1zv	18.0
10	Turbaslinsko	Bashkirian	C2b	10.0
11	Buzovyazovsk	Kizelian	C1ks1	44.0
12	Buzovyazovsk	Pashiiskian	D1b	2.8
13	Buzovyazovsk	Pashiiskian	D1h	64.0
14	Tolbazinskoy	Kizelian	C1ks1	23.3
15	Orenburg	Artinskian	Kashirian	2000.0

Figure 8. Multidimensional scaling of limestone reservoirs in the Ufa-Orensburg Region.



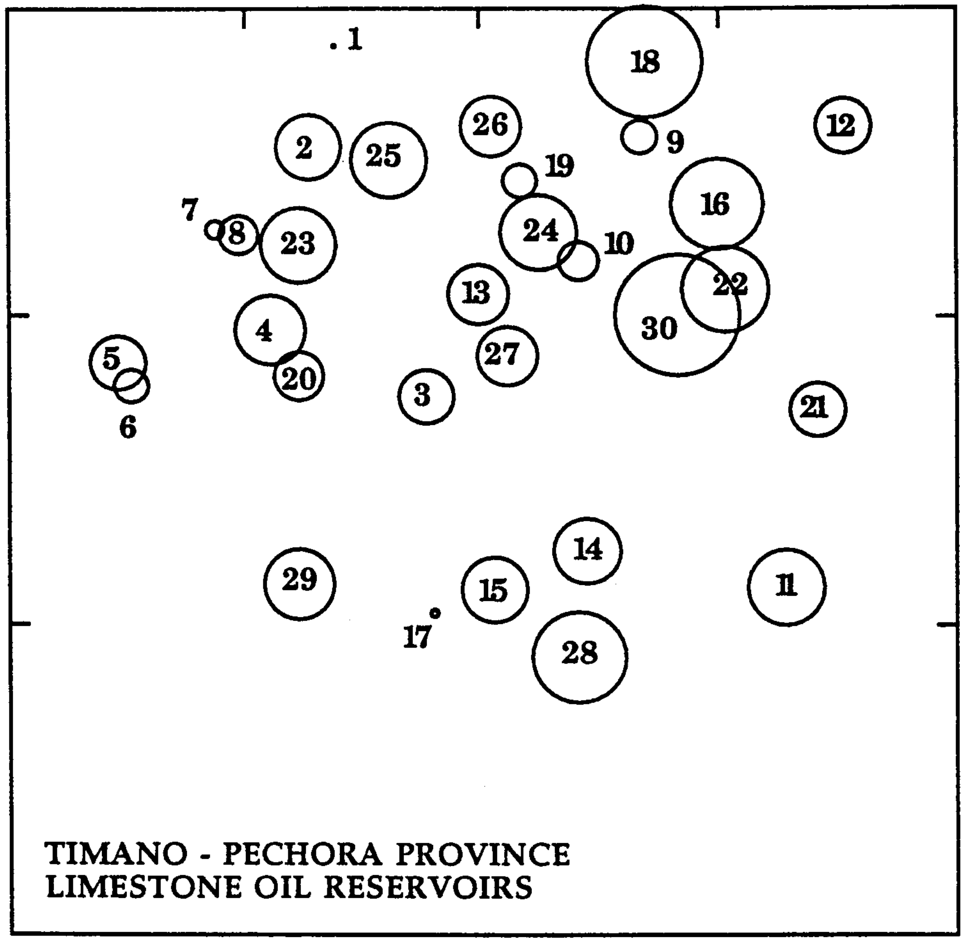
ID	FIELD	RESERVOIR AGE	OYIELD (t per day)
1	Sergeyevskoy	Bobrikovian	162.0
2	Sergeyevskoy	Pashiiskian	181.0
3	Sergeyevskoy	Mullinskian	150.0
4	Alkinskoye	Kynovian	22.4
5	Alkinskoye	Mullinskian	2.0
6	Shingakulsko	Bobrikovian	59.6
7	Shingakulsko	Pashiiskian	90.0
8	Shingakulsko	Mullinskian	10.0
9	Shingakulsko	Mullinskian	16.0
10	Davlekanovo	Kynovian	22.6
11	Davlekanovo	Pashiiskian	32.0
12	Rayevskiy	Kynovian	116.2
13	Rayevskiy	Pashiiskian	138.7
14	Shafranovsko	Kynovian	39.8
15	Shafranovsko	Pashiiskian	26.7
16	Shafranovsko	Starooskolia	27.9
17	Rakitovskoye	PashiiskD1b	119.3
18	Rakitovskoye	PashiiskD1h	117.9
19	Rakitovskoye	PashiiskD1h	18.4
20	Gordeyevskoy	Kynovian	20.5
21	Gordeyevskoy	Starooskolia	14.4
22	Gordeyevskoy	Takatinian	9.0
23	Balkanovskoy	Bobrikovian	48.8
24	Balkanovskoy	Pashiiskian	100.4
25	Balkanovskoy	Mullinskian	38.7
26	Kamensk	Pashiiskian	18.4
27	Kamensk	Starooskolia	32.5
28	Chernigov	Pashiiskian	17.1
29	Orlovskoye	Pashiiskian	116.0
30	Orlovskoye	Starooskolia	39.0
31	Iskrinskoye	Pashiiskian	12.0
32	Iskrinskoye	Pashiiskian	26.0
33	Kabakovskoye	Pashiiskian	21.0
34	Rodnikovskiy	Ardatovian	43.8
35	Nikolayevsko	Pashiiskian	38.4

Figure 9. Multidimensional scaling of sandstone reservoirs in the Ufa-Orensburg Region.



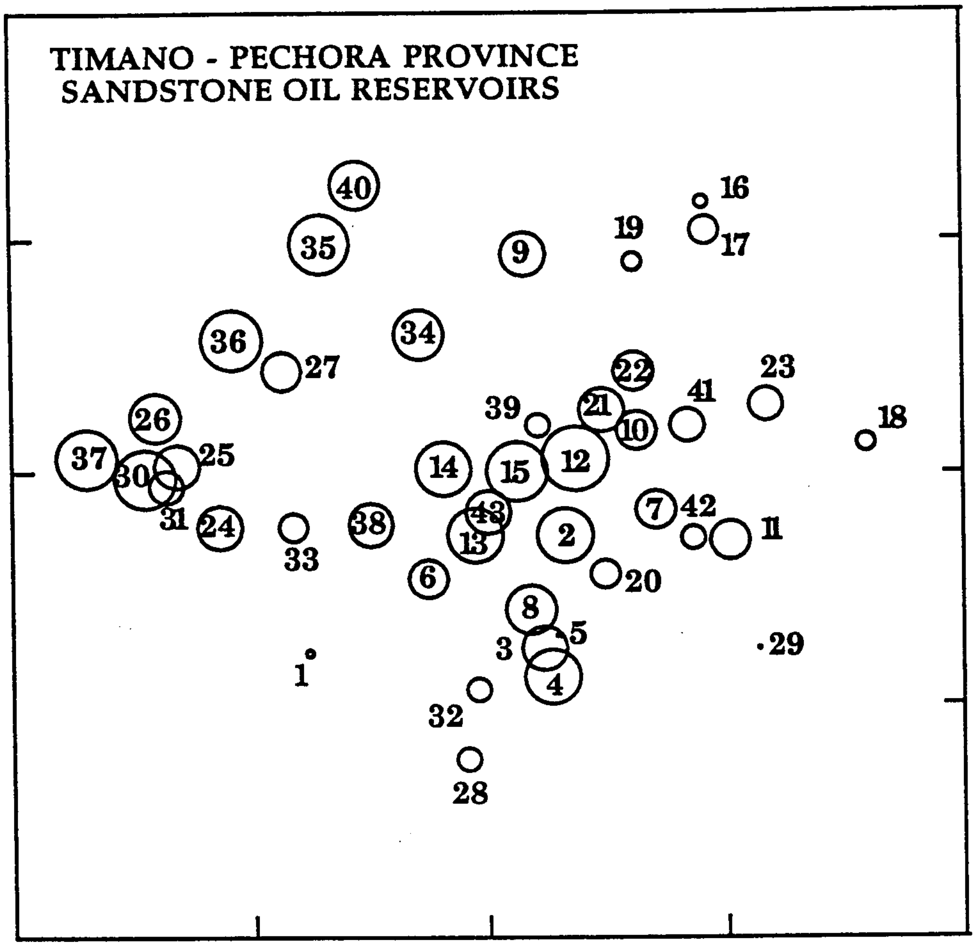
ID	FIELD	RESERVOIR AGE	OYIELD (t per day)
1	Ilovlindkiy	Aleksin V	73.0
2	Splavnushsko	Ardatov D2-IVa	46.0
3	Splavnushsko	Vorobye D2-V	33.5
4	Uritskiy	Tulian IV	63.6
5	Uritskiy	Tulian V	25.0
6	Rodionovskoy	Cherems	42.0
7	West Rybusha	Aleksin II	24.0
8	Goryuchkinsk	Aleksin V	6.0
9	Goryuchkinsk	Tulian I	80.0
10	Kolotovskoye	Melekes III-IV-V	42.0
11	Kolotovskoye	Tulian I	40.0
12	Kolotovskoye	Tulian II	20.0
13	Aleksandrovs	Ardatov D2-IV	18.6
14	Surovskoye	Tulian I-II	25.0
15	Peschano-Ume	Bobriko	20.0
16	Gruzinovskoy	Tulian V	51.0
17	Yelshanskoye	Tulian V	5.4
18	Atamanovka	Kynovia D3-I	5.7
19	Yazykovo	Tulian I-II	4.1
20	Yazykovo	Tulian V	8.0
21	Yazykovo	Bobriko	8.1
22	Irinovskoye	Tulian V	1.4
23	Guselskoye	Kynovia D3-Ia	31.0
24	Guselskoye	Kynovia D3-I	38.7
25	Guselskoye	Pashiis "D3-II	53.0
26	Guselskoye	Ardatov D2-IVa	13.3
27	Guselskoye	Vorobye D2-V	49.0
28	Trofimovskoy	Ardatov D2-IVa	11.0
29	Sokolovgorsk	Bobriko	26.0
30	Sokolovgorsk	Kynovia D3-I	5.0
31	Sokolovgorsk	Pashiis D3-II	190.0
32	Sokolovgorsk	Ardatov D2-IVa	8.6
33	Sokolovgorsk	Ardatov D2-IVb	8.0
34	Kvasnikovsko	Kynovia D3-I	65.0
35	Kvasnikovsko	Vorobye D2-V	106.8
36	Kvasnikovsko	Vorobye D2-VII	73.0
37	Pionerskoye	Ardatov D2-IVa	52.0
38	Pionerskoye	Vorobye D2-V-VI	111.0
39	Pionerskoye	Morsovi	28.0
40	Gryaznushins	Vorobye D2-V	8.0
41	Privolzhskoy	Ardatov D2-IVa	102.5
42	Rozovskoye	Ardatov D2-IVa	30.0
43	Rozovskoye	Ardatov D2-IVa	0.7
44	South Genera	Bobriko	17.7
45	Sovetskoye	Ardatov D2-IVa	46.0
46	Sovetskoye	Ardatov D2-IVb	28.3
47	Staritsa	Vereiia X	5.7
48	Staritsa	Bobriko	2.6
49	Furmanovskiy	Vereiia IX	5.0
50	Furmanovskiy	Bobriko	14.0
51	East Suslovs	Ardatov D2-IVb	105.0
52	East Suslovs	Vorobye D2-V	75.0
53	East Suslovs	Vorobye D2-V	71.0

Figure 10. Multidimensional scaling of sandstone reservoirs in the Lower Volga Region.



ID	FIELD	RESERVOIR AGE	OYIELD (t per day)
1	Dzherskoye	Ur Fammen IV	0.7
2	South Tebuks	Lr Fammen F1	37.4
3	West Tubeksk	Lr Fammen F1	25.0
4	West Tubeksk	Ur Siluri WK	62.0
5	Luzskoye	Lr Fammen F1	23.5
6	Luzskoye	Ur Frasni Fr-I	8.0
7	North Savino	Kungurian	4.0
8	North Savino	Tournaisi IV	11.2
9	Pashninskoy	Kungurian	8.0
10	Pashninskoy	Ur Fammen III	11.5
11	Upper Grubes	Ur Frasni	78.0
12	Usinsk	Sakmarian	25.4
13	Usinsk	Visean	36.1
14	Vozeyskoe	Domanikov III	38.2
15	Vozeyskoe	Domanikov I	38.2
16	Vozeyskoe	Sakmarian	160.0
17	Vozeyskoe	Domanikov II	2.0
18	Yareyyuskoye	Artinskia	500.0
19	Yareyyuskoye	Sakmarian	7.8
20	Khylchuyusko	Artinskia I	20.0
21	Pashshorskoy	Ur Frasni	24.1
22	Vaneyvisskoy	Ur Carbon	135.0
23	North Khose	Artinskia	77.9
24	Toraveyskoy	Artinskia	85.0
25	South Torave	Artinskia	69.3
26	Naulskoye	Artinskia	32.8
27	Laboganskoy	Tournaisi	36.7
28	Cherpayusko	Lr Devoni	178.0
29	Toboyskoye	Lr Devoni	57.0
30	Salyukinsko	Sakmarian	820.0

Figure 11. Multidimensional scaling of limestone reservoirs in the Timan-Pechora Region.



ID	FIELD	RESERVOIR	AGE	OYIELD (t per day)
1	Yagera	Ur Devon	III	2.7
2	Voy-Vozhskoy	Staroosk	Id	125.0
3	Nibelskoye	Pashiisk	Ia	50.0
4	Nibelskoye	Staroosk	Ic	140.0
5	Upper Omra	Pashiis	Ia	1.2
6	Upper Omra	Pashiis	Ib	35.0
7	Upper Omra	Staroos	Ic	40.0
8	Lower Omra	Pashiisk	Ia	100.0
9	Lower Omra	Staroosk	Ic	60.0
10	Dzherskoye	Pashiis	Ia	44.1
11	Dzherskoye	Pashiis	Ib	42.4
12	Dzherskoye	Staroos	Ic	392.8
13	West Tubeksk	Staroosk	Ic	126.0
14	West Tubeksk	Afonini	IIa	170.0
15	West Tubeksk	Eifelia	IIb	225.0
16	Lemyus	Kazanian		5.5
17	Izakovskoye	Kazanian		13.6
18	Luzskoye	Pashiisk	Ib	7.0
19	Michayuskoy	Staroos	Ic	6.8
20	North Savino	Pashiis	Ib	13.4
21	North Savino	Staroos	Ic	58.0
22	East Savinob	Pashiis	Ib	34.0
23	East Savinob	Staroos	Ic	23.0
24	Pashninskoy	Pashiis	Ia	66.7
25	Pashninskoy	Staroos	Ic	52.7
26	Pashninskoy	Staroos	Ic	112.0
27	Kyrtayelskoy	Staroosk	Ic	36.0
28	Kyrtayelskoy	Afoninia		10.6
29	Yugidskoye	Visean	IIa	2.0
30	Yugidskoye	Staroosk		192.0
31	Pechora-Kozh	Pashiisk		27.7
32	South Kurtay	Pashiis		12.0
33	North Kozhva	Pashiisk		20.0
34	North Kozhva	Staroosk	II	90.8
35	Upper Grubes	Staroosk		200.0
36	Upper Grubes	Staroosk		208.0
37	Usinsk	Staroosk		223.0
38	Khylchuyusko	Ufimian	P8	52.0
39	Khylchuyusko	Ufimian	P6	12.0
40	Pashshorskoy	Afoninia		80.0
41	Toraveyskoy	Ufimian		24.6
42	South Torave	Ufimian	P6	12.1
43	Naulskoye	Ufimian	P6	61.0

Figure 12. Multidimensional scaling of sandstone reservoirs in the Timan-Pechora Region.