Reservoir Performance of Fluid Systems with Widely Varying Composition (GOR)

A Simulation Approach

M. Sc. Thesis

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Declaration

I hereby declare that this Master of Science thesis has been performed in accordance to the regulations at the Norwegian University of Science and Technology, Trondheim, Norway.

Trondheim, December 15, 1997

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Preface

This thesis is submitted to the Department of Petroleum Engineering and Applied Geophysics at the Norwegian University of Science and Technology, Trondheim, in candidacy for the degree of Master of Science in Petroleum Engineering.

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Abstract

Reservoir performance depends on many factors such as drive mechanism, reservoir rock, and fluid properties. For depletion drive reservoirs, the principal drive mechanism is the expansion of the oil and gas initially in place. Main factors in depletion drive reservoirs are total cumulative compressibility, determined mostly by composition (GOR), saturation pressure and PVT properties, and relative permeability. In this work, the effect of initial composition (GOR) on recovery, plateau production rate, plateau production period, and decline constant has been investigated.

In order to analyze the effect of composition (GOR), near critical reservoir fluid has been used. Same PVT data have been used in all cases. While simulating as oil reservoir, different reservoir fluids have been obtained by changing bubble point pressure and fuild composition (GOR). Similarly, in order to get different initial producing GOR, saturation pressure and composition have been changed while simulating as gas reservoir. Reservoirs containing fluid from dead oil to lean gas have been considered in this way.

Material balance, two dimensional fine grid model and three dimensional coarse grid models have been used to investigate the effect on different performance parameters. The production well is completed in the centre of the reservoir in all simulation models. Reservoir pore volume is same in all models by keeping reservoir surface area and thickness same.

For oil reservoirs, depletion recovery of stock tank oil (STO) increases with increasing initial producing GOR. Then recovery reaches maximum value. After that, recovery decreases with increasing initial producing GOR and reaches minimum value for near critical oil.

For gas reservoirs, depletion drive recovery of STO increases monotonically with increasing initial producing GOR.

Recovery of STO from oil reservoirs depends on oil-gas relative permeabilities also in addition to initial producing GOR. STO recovery from gas reservoir is independent of critical gas saturation.

For oil reservoirs, for a given plateau production period of 5 years, plateau production rate initially increases with increasing initial producing GOR. Then plateau rate reaches a maximum value. After that, it decreases and is lowest for near critical oil. For gas reservoirs, for a given plateau production period of 5 years, plateau rate increases monotonically. Plateau production rate also depends on model used.

Plateau production period and decline constant also depend on initial producing GOR and simulation models used in simulating the reservoir.

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Chapter 1

Introduction

The reservoir performance under primary recovery by natural depletion depends on the drive mechanism, fluid and rock properties. The drive mechanisms can be classified as depletion drive, gascap drive, natural water drive, compaction drive or a combination of these mechanism.

Drive mechanisms can be identified based on geological data, testing data or pressure production data. In case of depletion drive, production is due to expansion of oil and gas initially in place. In gascap drive mechanism, gas in gascap expands as reservoir pressures declines with production. In water drive mechanism, water in the aquifer expands and provides energy. If large aquifer is associated with reservoir then it is called active water drive mechanism. In combination drive, more than two drive mechanisms are active.

In a depletion drive reservoir, initial reservoir pressure is higher than or equal to the bubble point pressure of the original fluid. Initially, only one phase is present in the reservoir. If reservoir pressure is greater than the saturation pressure, then production is due to expansion of single phase fluid present in the reservoir. In this case, rock and water compressibilities are also important because rock and water compressibilities are generally of the same order of magnitude as the compressibility of oil.

Below the bubble point pressure, gas is liberated from the saturated oil in oil reservoir. A free gas saturation develops in the reservoir. Liberated gas also expands as pressure decreases with production. Because gas compressibility is much larger than water and rock compressibilities, water and rock compressibilities are less important below the bubble point pressure. When gas saturation reaches the critical gas saturation then gas flows together with the oil. The producing GOR increases as reservoir pressure continues to decrease. Because liberated gas is produced and gas mobility increases rapidly, reservoir pressure drop accelerates. A detailed analysis of reservoir performance in depletion drive reservoirs has been done in this work. A typical production performance history of a depeltion drive reservoir under primary production is given is in **Fig. 1.**

Depletion reservoir performance depends strongly on reservoir fluid properties. Reservoir fluids are classified as black oil, volatile oil, gas condensate, wet gas, and dry gas on the basis of reservoir temperature and first stage separator conditions[1,2]. Reservoir fluids are classified on the basis of produced GOR.

In black oil reservoirs, reservoir temperature is far lower than critical temperature of the fluid. Initial producing GOR from black oil reservoirs typically in the range of 150-200 Sm^3/Sm^3. Producing GOR increases during production when reservoir pressure falls below the bubble point pressure. Stock tank oil gravity from such reservoirs is usually lower than 45 ^{o}API and is dark in color. Initial oil formation volume factor is lower than 2.0 RB/STB. Black oil properties change gradually below the bubble point pressure. Concentration of the heptanes plus is higher than 30 mole percent.

When reservoir temperature is near critical temperature of the mixture then it is known as a volatile oil. In this type of reservoir, initial producing GOR ranges from 200 to 500 Sm^3/Sm^3. Formation volume factor is greater than 2.0 RB/STB. STO specific gravity ranges from 35 to 40 ^{o}API and is brown, green or black in color. Oil properties change drastically below the bubble point pressure. Concentration of the heptanes plus is 12.5 to 30 mole percent.

Reservoir fluid is classified as gas condensate when reservoir temperature is higher than critical temperature but lower than the cricondentherm. In this type of reservoir, initial producing GOR ranges from 500 to 25000 Sm^3/Sm^3. Stock-tank liquid gravity ranges from 40 to 70 ^{o}API. The produced liquid can be of light colour, brown, orange, greenish or water white. Heptanes plus fraction concentration is generally lower than 12.5 mole percent. Particularly important to this type of reservoir is condensate yield, the inverse of producing GOR. Condensate yield varies from 10 to 300 STB/MMscf.

Reservoir fluid is classified as wet gas when reservoir temperature is higher than the cricondentherm and first stage separator condition located within the two-phase region. Initial producing GOR from this type of reservoir is higher than 9000 Sm^3/Sm^3 and remains constant during the life the reservoir. The stock tank liquid is generally water white.

Dry gas reservoirs have temperature higher than the cricondentherm and first stage separator condition lies outside the two phase envelope. There is no liquid formation either at the surface or in the reservoir. Initial producing GOR is very high and practically infinite.

Well performance is calculated by the inflow performance relationship. In oil reservoir, above the bubble point pressure, only single phase is present in the reservoir. So, performance relation is given by single phase flow equation. Oil mobility is important in this case. But when two phases are present then flow rate in given by the total mobility (i.e. oil and gas mobility). In gas reservoir, above the saturation pressure, only gas phase is present so gas mobility is used in flow calculation. But when two phases develop in the reservoir, then total mobility (oil and gas) is used in flow rate calculation.

Reservoir performance analysis has been done for wide range of fluid types in this work. Different performance parameters have been calculated.

Near well multiphase flow effects have also been investigated in this work. Different simulation models have been used to know the effect of near well flow phenomena.

Chapter 2

Fluid and Reservoir Data

2.1 PVT Data

Reservoir fluid properties have been generated using the Peng-Robinson equation of state with five C_{7+} fractions in PVT simulation package PVTx [4]. In order to cover whole range of reservoir fluid i.e. black oil to lean gas, bubble point pressure of the original fluid increased by incremental adding equilibrium gas (i.e. gas at initial bubble point pressure) till critical point is reached. This has been done by swelling experiment in PVTx. Final bubble point pressure of the fluid is 7394 psia which is near the critical point of the fluid. Black oil properties have been generated using CVD, CCE and DLE experiments on near critical fluid using PVTx. Generated PVT properties have been plotted in **Figs. 2** through **6**.

CCE and CVD generated PVT properties are close to each other compared to DLE experiment generated properties (as shown in Figs. 2 through 6). DLE gives heavier oil compared to CVD and CCE. Oil formation volume factor, solution GOR are high in CCE and CVD experiments compared to DLE experiment at any pressure. Oil viscosity is lower in CCE and CVD experiments than in DLE experiment at any pressure except at very low pressures. Solution oil gas ratio is higher in CCE and CVD experiments than in DLE experime. But gas viscosity is almost the same in all the experiments. Since CCE experiment gives the same compostion at original bubble point pressure so CCE experiment generated black oil properties have been used in this study. Maximum solution GOR is 700 Sm^3/Sm^3 and maximum solution oil gas ratio is 252 STB/MMscf as given in **Table 1**. and shown in **Figs**. **7** through **8**.

While simulating the reservoir, minimum initial producing GOR of 35 Sm^3/Sm^3 has been used which represents black oil. The maximum initial producing GOR of 26700 Sm^3/Sm^3 has been used which represents lean gas reservoir. Recovery and other performance indices have been generated at different initial producing GOR in the range mentioned above.

2.2 Relative Permeability data

Relative permeabilities play an important role in oil and gas recoveries. Hence it is necessary to use the most appropriate relative permeabilities in the simulation study.

Critical gas saturation has large effect on gas relative permeability and no effect on oil relative permeability. Critical oil saturation has effect on oil relative permeability only. Initial water saturation has effect on both oil and gas relative permeabilities.

In case of oil reservoir, critical gas saturation play an important role. With increase in critical gas saturation, Krg/Kro decreases for a given gas saturation hence oil recovery increases. High gas saturation is required before gas flows along with oil. Liberated gas expansion helps in reducing the reservoir pressure decline from the bubble point pressure to the reservoir pressure when gas saturation becomes equal to critical gas saturation. Once critical gas saturation is reached then gas flows along with oil.

In case of gas reservoirs, recovery does not vary with critical gas saturation.

In this study, relative permeabilities have been generated using Corey correlation[5]. Sensitivity analysis has been done taking different critical gas saturations[6]. In base case, critical gas saturation of 0.01 has been taken. In other two cases, critical gas saturations of 0.10 and 0.20 have been taken while simulating to see the effect of relative permeabilities on depletion recovery.

2.3 Reservoir data

Reservoir rock porosity has been taken as 0.30 and permeability of 5 md. Initial reservoir pressure has been used as 7500 psia. Thickness of the layer is 100 ft. In case of radial model, reservoir of 1500 ft external radius has been considered and grid cell thickness increases outside from the wellbore such that ratio of two consecutive radii is constant. This is done in order to get same pressure drop in all grids. Hence radial model represents fine grid model. Other Reservoir properties used in simulation study are given in **Table 2**.

Chapter 3

Reservoir Simulation Study

Reservoir simulation study has been performed using Eclipse 100 black oil simulator. Single cell material balance model, two-dimensional radial model and three-dimensional coarse grid models have been used in simulation study as shown in **Fig. 9**.

In case of material balance model, only one cell has been considered of 1500 ft radius and 100 ft thick (Fig. 9a).

In case of fine grid radial model, reservoir has been divided in 20 radial grid cells in radial direction and only one layer in vertical direction of thickness 100 ft. The outer radius of the reservoir is 1500 ft. Cell thickness in radial direction increases in such a way that ratio of radius of two consecutive grids is same. Whole angle of 360^o has been used while simulating the reservoir. The production well has been completed in the centre of the reservoir. Reservoir pore volume in this case is same as in material balance case (Fig. 9b).

In coarse grid model, for one case, grid dimensions of 300 ft x 300 ft x 100 ft have been used. Number of grid cells has been selected such that surface area of the reservoir is same as in the case of radial model. In this case, 9 x 9 x 1 gridcells have been used as shown in Fig 9c. Since reservoir surface area and reservoir thickness are same as in case of radial model so reservoir pore volume is also same. The production well has been completed in the centre of the reservoir i.e. in the central grid (5,5,1).

In another coarse grid model, grid dimensions of 200 ft x 200 ft x 100 ft have been used. Number of grids has been increased to 13 x 13 x 1 gridcells (Fig 9d) to have same reservoir pore volume. Well has been completed in the central grid (7,7,1).

In the third coarse grid model, grid dimensions have been decreased to 100 ft x 100 ft x 100 ft and number of gridcells increased to 27 x 26 x 1 (Fig. 9e). Well has been completed in such a way that it lies in the centre of the reservoir e.g. in the central cell (13,13,1).

Same PVT data as given in table 1 has been used in all simulation cases. In order to get different reservoir fluid, initial producing GOR and saturation pressure of the reservoir fluid have been changed in different cases(**Table 3**). If the bubble point of oil reservoir fluid increases then the value of initial producing GOR increases. This is done by changing values of initial solution GOR and initial solution OGR under keywords RSVD and RVVD respectively in Eclipse simulation data file. Similarly, in gas reservoirs, by changing OGR (initial producing GOR is inverse of initial OGR) in keyword RVVD, different initial producing GOR is obtained.

In order to simulate oil reservoir, original gas-oil contact is fixed on the top of the reservoir so that there is no initial free gas present in the reservoir. Then taking different bubble point pressure, different initial producing GOR is obtained in different cases. For simulating gas reservoir, original gas-oil contact is fixed at the bottom of the reservoir.

3.1 Reservoir Performance Analysis

Reservoir simulation study has been done using above simulation models and reservoir fluid. In order to get a general performance of a depletion drive reservoir, simuation has been performed taking 300 ft x 300 ft coarse grid model. Reservoir has been simulated as oil reservoir by fixing gas-oil contact at –5000 ft. Bubble point pressure of the reservoir fluid is taken as 5561 psia thus giving initial producing GOR of 315 Sm^3/Sm^3. Eclipse input data file for this case is given in **Table 4.** Results of simulation study are plotted in **Figs. 10** through **11**.

Initially reservoir pressure decreases very fast down to the bubble point pressure since production is due to expansion of reservoir fluid which is single phase oil. Producing gas is equal to initial solution GOR. But when reservoir pressure reaches the bubble point pressure then gas is liberated from the reservoir oil. Liberated gas remains in reservoir till gas saturation reaches to critical saturation. So, from the bubble point pressure to the pressure when gas saturation is equal to critical gas saturation, reservoir pressure decreases slowly. Once liberated gas saturation in the reservoir is higher than critical gas saturation then gas flows along with the oil. Then reservoir pressure drops fast.

3.2 STO Recovery Factor

Recovery factor is defined as the ratio of recoverable reserves to initial fluid in place. Recovery factor depends on various parameters such as drive mechanism, fluid and rock properties. In present work, recovery factors in depletion drive reservoirs have been calculated for different initial producing GOR.

In all the simulation cases, the well produces at full capacity from the very beginning. The minimum flowing bottomhole pressure considered is 500 psia. The production has been continued till a minimum oil rate of 0.1 STB/D or 500 years which ever happens first.

Using material balance model, STO recovery factor has been calculated for oil reservoirs and gas reservoirs. After simulating the reservoir with above mentioned reservoir and fluid properties, recovery factor has been calculated for different initial producing GOR.

First of all, reservoir has been simulated as oil reservoir by fixing initial oil-gas contact at –5000 ft while top of the reservoir is at –7000 ft. Hence initial gas-oil contact is at far above from reservoir top hence reservoir is having only oil initially. Then RS value has been selected as 196 scf/STB. Thus reservoir is undersaturated because the bubble point pressure is 1000 psia while the initial reservoir pressure is 7500 psia. Then Eclipse 100 has been used and reservoir performance for 500 years obtained. The recovery factor in this case is equal to 28.28 %. In next run, RS value has been changed to 323 scf/STB and the bubble point pressure to 1500 psia. After simulation, recovery factor of 32.49 % has been obtained in this case. Similarly, RS values have been changed in each run and different recovery factor values are obtained for different initial producing GOR. Recovery factor vs initial producing GOR is shown in **Fig. 12.** From Fig.12, it is clear that recovery of STO first increases with increasing initial producing GOR and reaches a maximum value at initial producing GOR of 80 Sm^3/Sm^3. Then recover factor decreases as initial producing GOR increases and reaches a minimum value at the highest initial producing GOR value of 700 Sm^3/Sm^3.

When simulating gas reservoir, initial gas-oil contact has been shifted to –15000 ft which is far below the reservoir bottom. Hence reservoir fluid will be gas when simulated in this condition. RV value has been selected as 6.9 STB/MMscf. Then simulation study has been done under above mentioned conditions. In that case, STO recovery is 91.73 %. Then RV value is changed in next run and recovery obtained is different. Recovery factors have been plotted in Fig. 12 for gas reservoirs also. Maximum STO recovery is in the case of lean gas reservoir when initial producing GOR is high and minimum for rich gas reservoir. STO recovery factor increases with increasing initial producing GOR monotonically. On semi-log plot, it seems straight line except at end points.

When simulating oil reservoir, recovery at highest initial producing GOR is about 16 %. When simulating gas reservoir, recovery at minimum initial producing GOR is also about 16 %. Hence near critical point, recovery is equal either simulating as oil reservoir or gas reservoir.

Recovery has also been calculated in two parts, one down to saturation pressure and other below the saturation pressure. Since low initial producing GOR oil reservoir is more undersaturated as shown in **Fig. 13** so the recovery down to saturation pressure is higher due to simple expansion of reservoir fluid as shown in **Fig. 14**. As saturation pressure increases, it becomes less undersaturated i.e. the difference between the initial reservoir pressure and the saturation pressure decreases so recovery down to saturation pressure is less as it reaches towards near critical oil. For near critical oil reservoir, the saturation pressure is close to the initial reservoir pressure so recovery down to the saturation pressure is almost negligible. At the same time, recovery below saturation pressure till abandonment condition first increases with increasing initial producing GOR and then decreases. But the change in the recovery below saturation pressure with initial producing GOR is very less i.e. it is almost constant below saturation pressure.

In case of gas reservoirs, for low initial producing GOR, recovery down to saturation pressure is negligible since initial reservoir pressure is close to saturation pressure. As reservoir becomes more undersaturated then recovery down to saturation pressure increases as shown in Fig. 13. This is due to the fact that high STO recovery is obtained before reservoir pressure reaches to saturation pressure. Recovery below saturation pressure is almost constant for most part of the initial GOR range and is less for very undersaturated gas reservoir where almost all recovery is from expansion of reservoir fluid.

In order to evaluate the effect of relative permeabilities on STO recovery[7] under solution gas drive, three different sets of relative permeabilities data have been used in simulation study. In case of base relative permeabilities, critical gas saturation of 0.01 has been used. Other sets of relative permeabilities have been generated using critical gas saturation of 0.10 and 0.20.

When critical gas saturation is high then high gas saturation is required before gas flows together with the oil (**Fig. 15**). In case of zero critical gas saturation, gas flows immediately after released from oil. But when critical gas saturation is say 0.20 then gas saturation in the reservoir must be higher than 0.20 before it can flow. Gas liberated from the oil remains in the reservoir until critical gas saturation is reached. Since gas compressibility is very large, it helps in recovery due to expansion of liberated gas. Hence if critical gas saturation is high then recovery of STO under depletion drive is high. Recoveries for three different cases of relative permeabilities have been calculated and shown in **Fig. 16**. In case of gas reservoirs, gas saturation never goes below critical gas saturation so recovery is unaffected by critical gas saturation. Hence there is no change in STO recoveries in case of gas reservoirs with relative permeabilities as shown in Fig. 16.

From above analysis, it is clear that STO recovery depends on initial producing GOR. At the near critical point, recovery is same either simulated as gas reservoir or oil reservoir. It is minimun in case of near critical oil. Maximum recovery is obtained in case of dry gas reservoir. Recovery is not monotonic function of initial producing GOR i.e. it increases with initial producing GOR and then decreases in case of oil reservoirs. But in case of gas reservoirs, recovery increases with increasing initial producing GOR.

3.3 Plateau Production Rate

After calculating recovery factors for different initial producing GOR, plateau production rate has been calculated for different initial producing GOR using different simulation models.

First of all, material balance model has been used for calculating plateau production rate for different initial producing GOR. For oil reservoir, well has been produced such that plateau production period is 5 years and STO plateau production rate is calculated for that particular initial producing GOR. Similarly plateau STO production rate is calculated for other initial producing GOR. In case of gas reservoirs also, plateau gas production is calculated such that plateau period is 5 years. Plateau gas production rate is different for different initial producing GOR. Plateau STO production rate for oil reservoirs and gas production rates for gas reservoirs are shown in **Fig. 17**.

For oil reservoirs, plateau rate increases first with increasing initial producing GOR and then decrease with increasing initial producing GOR. Maximum plateau rate is obtained for the initial producing GOR when gas saturation is lower than critical gas saturation at the end of plateau period of 5 years. In case of less initial producing GOR, gas is liberated at later time hence benefit of liberated gas expansion is not obtained. In case of high initial producing GOR, gas is liberated before 5 years and gas saturation becomes higher than critical gas saturation so liberated gas flows with oil as shown in **Figs. 18** through **19.**

But for gas reservoir, plateau production rate increases with increasing initial producing GOR. Plateau production rate of STO has also been calculated for gas reservoirs. STO plateau rate decreases with increasing initial producing GOR as shown in **Fig. 20**. In **Fig. 21**, plateau production rates of STO and gas are shown in case of gas reservoirs.

Plateau production rate has also been calculated using fine grid radial model. In radial case, for oil reservoirs, plateau production rate first decreases then increases and finally decreases as it approches towards near critical oil. In case of gas reservoirs, plateau gas production rate increases as shown in **Fig. 22**. Plateau production rates for material balance and radial case are shown in **Fig. 23**.

In case of oil reservoir radial model, this unusual trend is because of producing GOR variation with time for different initial producing GOR. In case of maximum plateau rate, liberated gas saturation is just below critical gas saturation at the end of plateau period. Hence, full advantage of gas expansion is obtained as shown in **Fig. 24** through **25**. In case of point c in Fig. 23, reservoir pressure is just equal to saturation pressure at the end of plateau period as shown in **Fig. 26**. Other production performance parameters are given in **Fig. 27**.

3.4 Plateau Production Period

Plateau production rates have been calculated using material balance and fine grid radial models. In this section, for a given plateau rate for five years in radial model, plateau production periods in other coarse grid models have been calculated. Same radial model has been used as described above.

For oil reservoir of initial producing GOR of 133 Sm^3/Sm^3, plateau production rate for 5 years has been calculated using radial model. Plateau production rate of 1130 STB/D obtained in radial model case. When coarse grid 300 ft x 300 ft x 100 ft model is used then plateau production period of 6.27 years obtained for the same plateau production rate. Hence in case of coarse grid model, plateau production period is higher than in radial grid model. When coarse grid 200 ft x 200 ft x 100 ft model is used then plateau production period decreased to 6.08 years but still higher than radial grid model. Using 100 ft x 100 ft coarse grid model, plateau period of 5.75 obtained. In this way, if grid size is decreased then plateau period will decrease till it reaches to radial grid model calculated plateau period. Plateau period and other production data for different models are shown in **Figs**. **28** through **29**.

For gas reservoir with initial producing GOR of 8192 Sm^3/Sm^3, plateau production rate of gas has been calculated which is 12750 Mscf/D for 5 years in radial model case. Other coarse grid models have been used to calculate the plateau production period for the same plateau production rate. Plateau production period is 7.25 years for 300 ft x 300 ft x 100 ft coarse grid model, 7.09 years for 200 ft x 200 ft x 100 ft coarse grid model, 6.32 years for 100 ft x 100 ft x 100 ft coarse grid model and 6.13 years for 50 ft x 50 ft x 100 ft coarse grid model as shown in **Fig. 30**. Plateau production period decreases as grid dimension is decreased and approches to radial model calculated plateau period for very fine grid dimension. Other performance parameters variation in different simulation models are shown in **Fig. 31**.

Hence grid size selection is important in calculating plateau production period because number of wells to be drilled for developing the field depends on plateau production and period.

Plateau production periods in fine grid and other models have been calculated for different initial producing GOR for oil and gas reservoirs. For a plateau period of 5 years for fine grid radial model, plateau rate has been obtained for a particular initial producing GOR. Same plateau rate has been used to calculate plateau period in different models for that initial producing GOR. In this way, plateau period has been calculated for the whole range of initial producing GOR for all the four simulation models and plotted in **Fig. 32**.

Plateau period increases with increasing initial producing GOR. Then plateau period reaches a maximum value. After that, plateau period decreases with increasing initial producing GOR and is minimum for near critical oil reservoir. Same trend is obtained for all the simulation models for a given plateau period of 5 years for radial model.

For gas reservoirs, plateau period increases with increasing initial producing GOR. Then plateau period reaches a maximum value and after that it decreases with increasing initial producing GOR.

There is discontinuity in plateau period between oil reservoir and gas reservoir for a 5 years plateau period in radial model.

3.5 Decline Constant

Depletion Decline Constant used in Arp's equation is defined as the ratio of pseudo-staedy state production rate to the recoverable reserves. This decline constant has been calculated for different initial producing GOR. Variation of decline constatnt has been calculated for different initial producing GOR and shown in **Fig**. **33**. Decline constatnt has been calculated using both material balance and fine grid radial model plateau production rate. Decline rate increases monotonically with increasing initial producing GOR for both oil and gas reservoirs.

In case of oil reservoirs, decline constant is about 5 percent per year for low initial producing GOR. But it is about 14 percent per year for near critical oil . The variation from low value to high value of decline constant is gradual. But decline constant is high in material balance model than in fine grid radial model. The difference is due to high plateau production rate in case of material balance model compared to fine grid radial model. For near critical oil reservoir, plateau production rate is less but recovery factor is also less hence recoverable reserves becomes less resulting in high decline constant.

For gas reservoirs, decline constant varies between 11 percent per year to 14 percent per year. But difference in material balance and fine grid radial calculated decline constants is high than that in oil reservoirs. For very high initial producing GOR, decline constant is same for both material balance and fine grid radial model. Hence for dry gas reservoirs, grid size is not important as far as recovery and decline constant are concerned.

Conclusions

1. For oil reservoirs, depletion recovery of stock tank oil (STO) increases with increasing initial producing GOR. Then recovery reaches maximum value. After that, recovery decreases with increasing initial producing GOR and reaches minimum value for near critical oil.

2. For gas reservoirs, depletion drive recovery of STO increases monotonically with increasing initial producing GOR.

3. Recovery of STO from oil reservoirs depends on oil-gas relative permeabilities also in addition to initial producing GOR. STO recovery from gas reservoirs is independent of critical gas saturation.

4. Plateau production rate initially increases with increasing initial producing GOR then decreases in case of oil reservoirs but increases monotonically in gas reservoirs. Plateau production rate also depends on simulation model used for simulating the reservoir. Plateau production rate is higher in material balance model than in fine grid radial model.

5. For a given plateau production rate, plateau production period is different in different simulation models. Plateau production period is higher in coarse grid model than in radial models. Plateau producition period decreases as gridcell size decreases for a given plateau production rate.

Nomenclature

B_o Oil formation volume factor, RB/STB

μ_o Oil viscosity, cp

μ_g Gas viscosity, cp

R_v Solution oil gas ratio, STB/Mscf

B_{gd} Dry gas formation volume factor, RB/Mscf

R_S Solution gas oil ratio, Mscf/STB

GOR Gas oil ratio, Sm^3/Sm^3

P_b Bubble point pressure, psia

Ps Saturation pressure , psia

RO Reservoir oil

RG Reservoir gas

RF Recovery factor, %

RFpb Recovery factor down to bubble point pressure, %

MB Material Balance

20R Radial grid model with 20 grids in radial direction

SI Conversion Factors

Scf/STB x 0.17809 = 1 Sm^3/Sm^3

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APPENDIX

Table 1 - Reservoir Fluid Properties

Pressure	Solution Gas-oil Ratio	Solution Oil-gas Ratio	Oil Formation volume factor	Oil Viscosity	Gas Formation volume factor	Gas Viscosity
psia	Mscf/STB	STB/Mscf	RB/STB	cp	RB/Mscf	cp
100	0.007435	0.037495	1.06436	1.033550	37.293375	0.01298
500	0.080016	0.009208	1.11894	0.711450	7.035515	0.01375
1000	0.196281	0.006931	1.19029	0.557690	3.407924	0.01470
1500	0.323453	0.008160	1.26291	0.465780	2.229034	0.01600
1750	0.389896	0.009405	1.29940	0.430980	1.899885	0.01683
2000	0.458107	0.011032	1.33603	0.401170	1.657270	0.01778
2250	0.528087	0.013052	1.37285	0.375310	1.472284	0.01887
2500	0.599871	0.015489	1.40991	0.352670	1.327606	0.02010
2750	0.673507	0.018370	1.44727	0.332690	1.212231	0.02147
3000	0.749049	0.021724	1.48499	0.314950	1.118832	0.02296
3250	0.826555	0.025577	1.52311	0.299130	1.042346	0.02458
3500	0.906084	0.029952	1.56168	0.284950	0.979169	0.02632
3750	0.987718	0.034867	1.60075	0.272180	0.926667	0.02818
4000	1.071587	0.040332	1.64041	0.260630	0.882874	0.03014
4250	1.157915	0.046351	1.68081	0.250100	0.846292	0.03222
4500	1.247079	0.052920	1.72217	0.240400	0.815755	0.03442
4750	1.339677	0.060032	1.76485	0.231350	0.790342	0.03676
5000	1.436603	0.067688	1.80936	0.222740	0.769319	0.03924
5250	1.539112	0.075907	1.85641	0.214390	0.752099	0.04191
5561	1.677083	0.086997	1.91995	0.204090	0.735314	0.04555
5750	1.768400	0.094283	1.96226	0.197750	0.727380	0.04799
6000	1.900717	0.104715	2.02404	0.189120	0.719356	0.05155
6250	2.050585	0.116321	2.09481	0.180050	0.714114	0.05562
6500	2.225486	0.129577	2.17858	0.170300	0.711829	0.06040
6750	2.439073	0.145336	2.28270	0.159480	0.713043	0.06625
7000	2.719925	0.165526	2.42267	0.146870	0.719255	0.07392
7250	3.164035	0.196474	2.65120	0.130080	0.735790	0.08589
7394	3.926718	0.252518	3.06455	0.108140	0.778592	0.10733
7500	3.926718	0.252518	3.05406	0.109660	0.775911	0.10884

Table 2 : Reservoir properties used in simulation study

Reservoir external radius, ft	1500
Reservoir thickness, ft	100
Porosity, %	30
Absolute Permeability, md	6
Initial Reservoir pressure, psia	7500
Minimum bottomhole flowing pressure, psia	500
Irreducible water saturation, %	25
Reservoir Temperature, oF	266

Table 3 : Oil and gas PVT properties used in reservoir simulation study, ECL100 format

Solution Gas oil Ratio	Oil Pressure psia	Oil FVF Bo RB/STB	Oil Viscosity cp
PVTO			
0.00744	100	1.06436	1.03355
	500	1.05959	1.08629
	1000	1.05418	1.15051
	1500	1.04928	1.21294
	1750	1.04700	1.24351
	2000	1.04482	1.27366
	2250	1.04273	1.30340
	2500	1.04073	1.33274
	2750	1.03881	1.36168
	3000	1.03697	1.39024
	3250	1.03520	1.41842
	3500	1.03349	1.44623
	3750	1.03185	1.47368
	4000	1.03027	1.50077
	4250	1.02874	1.52751
	4500	1.02727	1.55390
	4750	1.02584	1.57996
	5000	1.02447	1.60569
	5250	1.02313	1.63110
	5561	1.02153	1.66226
	5750	1.02059	1.68096
	6000	1.01938	1.70542
	6250	1.01820	1.72958
	6500	1.01706	1.75345
	6750	1.01595	1.77702
	7000	1.01487	1.80031
	7250	1.01382	1.82331
	7500	1.01280	1.84604 /
0.08002	500	1.11894	0.71145
	1000	1.11056	0.76695
	1500	1.10311	0.82141
	1750	1.09967	0.84826
	2000	1.09641	0.87486
	2250	1.09331	0.90122
	2500	1.09036	0.92733
	2750	1.08754	0.95320
	3000	1.08484	0.97883
	3250	1.08226	1.00423
	3500	1.07979	1.02939
	3750	1.07742	1.05432
	4000	1.07514	1.07902
	4250	1.07295	1.10349
	4500	1.07085	1.12773
	4750	1.06882	1.15175
	5000	1.06686	1.17555
	5250	1.06497	1.19913
	5561	1.06271	1.22815
	5750	1.06138	1.24563
	6000	1.05967	1.26856
	6250	1.05802	1.29128
	6500	1.05642	1.31378
	6750	1.05487	1.33608
	7000	1.05337	1.35818
	7250	1.05191	1.38007
	7500	1.05049	1.40176 /
0.19628	1000	1.19029	0.55769
	1500	1.17987	0.60499
	1750	1.17513	0.62843
	2000	1.17065	0.65172
	2250	1.16642	0.67488
	2500	1.16240	0.69790
	2750	1.15860	0.72078
	3000	1.15497	0.74351
	3250	1.15152	0.76610
	3500	1.14822	0.78855
	3750	1.14507	0.81086
	4000	1.14205	0.83302
	4250	1.13916	0.85504
	4500	1.13639	0.87691
	4750	1.13372	0.89864
	5000	1.13116	0.92023
	5250	1.12869	0.94166
	5561	1.12575	0.96812
	5750	1.12402	0.98410

	6000	1.12181	1.00509
	6250	1.11967	1.02595
	6500	1.11761	1.04665
	6750	1.11561	1.06721
	7000	1.11367	1.08763
	7250	1.11180	1.10789
	7500	1.10998	1.12802 /
0.32345	1500	1.26291	0.46578
	1750	1.25662	0.48636
	2000	1.25072	0.50687
	2250	1.24518	0.52732
	2500	1.23995	0.54770
	2750	1.23501	0.56801
	3000	1.23034	0.58825
	3250	1.22590	0.60842
	3500	1.22168	0.62851
	3750	1.21766	0.64852
	4000	1.21383	0.66845
	4250	1.21017	0.68830
	4500	1.20666	0.70806
	4750	1.20331	0.72774
	5000	1.20009	0.74733
	5250	1.19700	0.76683
	5561	1.19332	0.79097
	5750	1.19116	0.80556
	6000	1.18841	0.82478
	6250	1.18575	0.84391
	6500	1.18319	0.86294
	6750	1.18071	0.88187
	7000	1.17832	0.90071
	7250	1.17601	0.91944
	7500	1.17377	0.93807 /
0.3899	1750	1.29940	0.43098
	2000	1.29268	0.45021
	2250	1.28638	0.46941
	2500	1.28046	0.48857
	2750	1.27488	0.50768
	3000	1.26960	0.52676
	3250	1.26461	0.54579
	3500	1.25988	0.56477
	3750	1.25537	0.58370
	4000	1.25109	0.60258
	4250	1.24700	0.62140
	4500	1.24309	0.64016
	4750	1.23935	0.65886
	5000	1.23577	0.67750
	5250	1.23234	0.69607
	5561	1.22825	0.71907
	5750	1.22587	0.73300
	6000	1.22282	0.75136
	6250	1.21988	0.76965
	6500	1.21705	0.78786
	6750	1.21432	0.80600
	7000	1.21168	0.82405
	7250	1.20913	0.84203
	7500	1.20666	0.85992 /
0.45811	2000	1.33603	0.40117
	2250	1.32889	0.41917
	2500	1.32220	0.43717
	2750	1.31592	0.45514
	3000	1.30999	0.47310
	3250	1.30440	0.49104
	3500	1.29910	0.50895
	3750	1.29407	0.52684
	4000	1.28929	0.54469
	4250	1.28474	0.56252
	4500	1.28040	0.58030
	4750	1.27625	0.59805
	5000	1.27228	0.61576
	5250	1.26848	0.63342
	5561	1.26397	0.65533
	5750	1.26134	0.66860
	6000	1.25797	0.68612
	6250	1.25474	0.70358
	6500	1.25162	0.72098
	6750	1.24861	0.73833
	7000	1.24571	0.75561
	7250	1.24291	0.77284
	7500	1.24021	0.79000 /
0.52809	2250	1.37285	0.37531
	2500	1.36531	0.39219
	2750	1.35825	0.40908
	3000	1.35161	0.42596
	3250	1.34535	0.44285
	3500	1.33944	0.45973
	3750	1.33384	0.47661
	4000	1.32853	0.49348
	4250	1.32348	0.51034
	4500	1.31867	0.52718
	4750	1.31408	0.54401
	5000	1.30970	0.56081
	5250	1.30550	0.57758
	5561	1.30053	0.59841
	5750	1.29763	0.61105

	6000	1.29393	0.62773
	6250	1.29038	0.64438
	6500	1.28696	0.66099
	6750	1.28366	0.67756
	7000	1.28048	0.69408
	7250	1.27742	0.71056
	7500	1.27445	0.72700 /
0.59987	2500	1.40991	0.35267
	2750	1.40199	0.36851
	3000	1.39456	0.38437
	3250	1.38758	0.40025
	3500	1.38100	0.41615
	3750	1.37478	0.43206
	4000	1.36889	0.44798
	4250	1.36330	0.46390
	4500	1.35798	0.47983
	4750	1.35292	0.49575
	5000	1.34809	0.51167
	5250	1.34348	0.52759
	5561	1.33801	0.54737
	5750	1.33483	0.55938
	6000	1.33077	0.57525
	6250	1.32688	0.59110
	6500	1.32313	0.60693
	6750	1.31953	0.62273
	7000	1.31605	0.63851
	7250	1.31270	0.65426
	7500	1.30947	0.66997 /
0.67351	2750	1.44727	0.33269
	3000	1.43898	0.34757
	3250	1.43121	0.36249
	3500	1.42389	0.37744
	3750	1.41700	0.39242
	4000	1.41048	0.40742
	4250	1.40430	0.42245
	4500	1.39844	0.43749
	4750	1.39287	0.45255
	5000	1.38756	0.46761
	5250	1.38249	0.48269
	5561	1.37650	0.50145
	5750	1.37301	0.51285
	6000	1.36857	0.52793
	6250	1.36431	0.54300
	6500	1.36022	0.55807
	6750	1.35628	0.57313
	7000	1.35250	0.58817
	7250	1.34885	0.60320
	7500	1.34533	0.61820 /
0.74905	3000	1.48499	0.31495
	3250	1.47635	0.32895
	3500	1.46823	0.34300
	3750	1.46060	0.35708
	4000	1.45340	0.37121
	4250	1.44659	0.38537
	4500	1.44014	0.39956
	4750	1.43401	0.41379
	5000	1.42818	0.42803
	5250	1.42262	0.44230
	5561	1.41606	0.46007
	5750	1.41225	0.47088
	6000	1.40740	0.48519
	6250	1.40276	0.49951
	6500	1.39830	0.51383
	6750	1.39401	0.52815
	7000	1.38989	0.54248
	7250	1.38593	0.55680
	7500	1.38210	0.57111 /
0.82656	3250	1.52311	0.29913
	3500	1.51412	0.31231
	3750	1.50569	0.32555
	4000	1.49774	0.33884
	4250	1.49025	0.35217
	4500	1.48315	0.36555
	4750	1.47643	0.37897
	5000	1.47004	0.39242
	5250	1.46397	0.40591
	5561	1.45680	0.42273
	5750	1.45264	0.43297
	6000	1.44735	0.44653
	6250	1.44229	0.46011
	6500	1.43744	0.47372
	6750	1.43278	0.48733
	7000	1.42830	0.50095
	7250	1.42400	0.51459
	7500	1.41986	0.52822 /
0.90608	3500	1.56168	0.28495
	3750	1.55236	0.29738
	4000	1.54361	0.30987
	4250	1.53537	0.32241
	4500	1.52759	0.33501
	4750	1.52022	0.34766
	5000	1.51323	0.36036
	5250	1.50659	0.37309

	5561	1.49878	0.38900
	5750	1.49425	0.39869
	6000	1.48849	0.41153
	6250	1.48298	0.42441
	6500	1.47771	0.43731
	6750	1.47266	0.45023
	7000	1.46781	0.46318
	7250	1.46314	0.47614
	7500	1.45866	0.48912 /
0.98772	3750	1.60075	0.27218
	4000	1.59112	0.28391
	4250	1.58207	0.29571
	4500	1.57354	0.30757
	4750	1.56548	0.31948
	5000	1.55785	0.33145
	5250	1.55061	0.34347
	5561	1.54209	0.35850
	5750	1.53716	0.36766
	6000	1.53090	0.37981
	6250	1.52493	0.39201
	6500	1.51921	0.40423
	6750	1.51373	0.41650
	7000	1.50848	0.42878
	7250	1.50343	0.44110
	7500	1.49858	0.45344 /
1.07159	4000	1.64041	0.26063
	4250	1.63049	0.27172
	4500	1.62115	0.28287
	4750	1.61234	0.29409
	5000	1.60401	0.30536
	5250	1.59612	0.31670
	5561	1.58685	0.33088
	5750	1.58150	0.33954
	6000	1.57471	0.35103
	6250	1.56822	0.36257
	6500	1.56203	0.37415
	6750	1.55610	0.38577
	7000	1.55042	0.39742
	7250	1.54497	0.40911
	7500	1.53974	0.42083 /
1.15792	4250	1.68081	0.25010
	4500	1.67060	0.26058
	4750	1.66098	0.27114
	5000	1.65190	0.28176
	5250	1.64331	0.29244
	5561	1.63324	0.30581

	5750	1.62742	0.31399
	6000	1.62006	0.32484
	6250	1.61304	0.33575
	6500	1.60633	0.34671
	6750	1.59993	0.35771
	7000	1.59379	0.36876
	7250	1.58791	0.37985
	7500	1.58226	0.39097 /
1.24708	4500	1.72217	0.24040
	4750	1.71168	0.25032
	5000	1.70178	0.26032
	5250	1.69244	0.27038
	5561	1.68150	0.28298
	5750	1.67519	0.29069
	6000	1.66721	0.30094
	6250	1.65961	0.31124
	6500	1.65236	0.32160
	6750	1.64544	0.33202
	7000	1.63882	0.34247
	7250	1.63247	0.35298
	7500	1.62639	0.36353 /
1.33968	4750	1.76485	0.23135
	5000	1.75407	0.24074
	5250	1.74391	0.25020
	5561	1.73203	0.26207
	5750	1.72519	0.26934
	6000	1.71654	0.27900
	6250	1.70831	0.28872
	6500	1.70048	0.29851
	6750	1.69300	0.30835
	7000	1.68585	0.31824
	7250	1.67902	0.32818
	7500	1.67246	0.33817 /
1.4366	5000	1.80936	0.22274
	5250	1.79829	0.23163
	5561	1.78539	0.24279
	5750	1.77796	0.24962
	6000	1.76859	0.25873
	6250	1.75968	0.26789
	6500	1.75121	0.27712
	6750	1.74313	0.28640
	7000	1.73541	0.29575
	7250	1.72804	0.30514
	7500	1.72098	0.31459 /
1.53911	5250	1.85641	0.21439

```
             5561    1.84236    0.22486
             5750    1.83430    0.23128
             6000    1.82412    0.23984
             6250    1.81447    0.24846
             6500    1.80529    0.25714
             6750    1.79655    0.26589
             7000    1.78821    0.27470
             7250    1.78025    0.28356
             7500    1.77263    0.29248 /

1.67708      5561    1.91995    0.20409
             5750    1.91097    0.21001
             6000    1.89966    0.21790
             6250    1.88895    0.22586
             6500    1.87878    0.23389
             6750    1.86911    0.24198
             7000    1.85990    0.25014
             7250    1.85111    0.25835
             7500    1.84271    0.26663 /

 1.7684      5750    1.96226    0.19775
             6000    1.95017    0.20525
             6250    1.93872    0.21281
             6500    1.92787    0.22044
             6750    1.91756    0.22814
             7000    1.90775    0.23591
             7250    1.89839    0.24373
             7500    1.88946    0.25162 /

1.90072      6000    2.02404    0.18912
             6250    2.01150    0.19617
             6500    1.99961    0.20328
             6750    1.98834    0.21046
             7000    1.97762    0.21771
             7250    1.96741    0.22502
             7500    1.95768    0.23239 /

2.05059      6250    2.09481    0.18005
             6500    2.08171    0.18665
             6750    2.06930    0.19331
             7000    2.05751    0.20003
             7250    2.04630    0.20682
             7500    2.03561    0.21368 /

2.22549      6500    2.17858    0.17030
             6750    2.16477    0.17643
             7000    2.15168    0.18263
             7250    2.13924    0.18889
             7500    2.12741    0.19521 /
```

```
 2.43907      6750    2.28270    0.15948
              7000    2.26793    0.16512
              7250    2.25393    0.17083
              7500    2.24062    0.17659 /

 2.71993      7000    2.42267    0.14687
              7250    2.40649    0.15197
              7500    2.39114    0.15714 /

 3.16404      7250    2.65120    0.13008
              7500    2.63242    0.13451 /

 3.92672      7394    3.06455    0.10814
              7500    3.05406    0.10966 /

/

-------- --------- ---------- -------------
Pressure  Solution   Gas FVF      Gas
           OGR, Rv     Bgd     Viscosity
Psia      STB/Mscf   RB/Mscf      cp
-------- --------- ---------- -------------
PVTG
     100  0.037495  37.293375   0.012979
          0.000000  37.293375   0.012979 /

     500  0.009208   7.035515   0.013746
          0.000000   7.035515   0.013746 /

    1000  0.006931   3.407924   0.014695
          0.000000   3.407924   0.014695 /

    1500  0.008160   2.229034   0.015998
          0.006931   2.223060   0.016007
          0.000000   2.223060   0.016007 /

    1750  0.009405   1.899885   0.016825
          0.008160   1.899427   0.016813
          0.006931   1.894030   0.016832
          0.000000   1.894030   0.016832 /

    2000  0.011032   1.657270   0.017782
          0.009405   1.657862   0.017748
          0.008160   1.657500   0.017731
          0.006931   1.652615   0.017760
          0.000000   1.652615   0.017760 /

    2250  0.013052   1.472284   0.018874
```

	0.011032	1.473542	0.018807
	0.009405	1.474088	0.018761
	0.008160	1.473768	0.018738
	0.006931	1.469346	0.018780
	0.000000	1.469346	0.018780 /
2500	0.015489	1.327606	0.020103
	0.013052	1.329237	0.019992
	0.011032	1.330324	0.019908
	0.009405	1.330781	0.019849
	0.008160	1.330469	0.019819
	0.006931	1.326469	0.019873
	0.000000	1.326469	0.019873 /
2750	0.018370	1.212231	0.021467
	0.015489	1.214001	0.021302
	0.013052	1.215354	0.021167
	0.011032	1.216244	0.021064
	0.009405	1.216590	0.020993
	0.008160	1.216264	0.020957
	0.006931	1.212651	0.021024
	0.000000	1.212651	0.021024 /
3000	0.021724	1.118832	0.022963
	0.018370	1.120552	0.022731
	0.015489	1.121958	0.022537
	0.013052	1.123025	0.022381
	0.011032	1.123709	0.022260
	0.009405	1.123933	0.022177
	0.008160	1.123582	0.022135
	0.006931	1.120321	0.022213
	0.000000	1.120321	0.022213 /
3250	0.025577	1.042346	0.024583
	0.021724	1.043858	0.024275
	0.018370	1.045148	0.024013
	0.015489	1.046200	0.023794
	0.013052	1.046989	0.023616
	0.011032	1.047468	0.023478
	0.009405	1.047569	0.023384
	0.008160	1.047186	0.023336
	0.006931	1.044244	0.023426
	0.000000	1.044244	0.023426 /
3500	0.029952	0.979169	0.026322
	0.025577	0.980342	0.025929
	0.021724	0.981375	0.025590
	0.018370	0.982260	0.025299
	0.015489	0.982978	0.025056

	0.013052	0.983501	0.024859
	0.011032	0.983785	0.024706
	0.009405	0.983766	0.024600
	0.008160	0.983349	0.024547
	0.006931	0.980696	0.024647
	0.000000	0.980696	0.024647 /
3750	0.034867	0.926667	0.028176
	0.029952	0.927389	0.027690
	0.025577	0.928052	0.027264
	0.021724	0.928646	0.026896
	0.018370	0.929157	0.026580
	0.015489	0.929565	0.026315
	0.013052	0.929841	0.026099
	0.011032	0.929942	0.025932
	0.009405	0.929808	0.025816
	0.008160	0.929356	0.025758
	0.006931	0.926965	0.025868
	0.000000	0.926965	0.025868 /
4000	0.040332	0.882874	0.030142
	0.034867	0.883053	0.029555
	0.029952	0.883248	0.029036
	0.025577	0.883450	0.028581
	0.021724	0.883645	0.028186
	0.018370	0.883815	0.027847
	0.015489	0.883939	0.027561
	0.013052	0.883987	0.027329
	0.011032	0.883919	0.027148
	0.009405	0.883679	0.027024
	0.008160	0.883194	0.026960
	0.006931	0.881037	0.027079
	0.000000	0.881037	0.027079 /
4250	0.046351	0.846292	0.032222
	0.040332	0.845852	0.031527
	0.034867	0.845502	0.030908
	0.029952	0.845227	0.030358
	0.025577	0.845014	0.029875
	0.021724	0.844848	0.029455
	0.018370	0.844710	0.029095
	0.015489	0.844576	0.028791
	0.013052	0.844416	0.028543
	0.011032	0.844193	0.028350
	0.009405	0.843855	0.028217
	0.008160	0.843339	0.028149
	0.006931	0.841394	0.028276
	0.000000	0.841394	0.028276 /

4500	0.052920	0.815755	0.034422	
	0.046351	0.814642	0.033612	
	0.040332	0.813681	0.032883	
	0.034867	0.812861	0.032232	
	0.029952	0.812166	0.031654	
	0.025577	0.811583	0.031146	
	0.021724	0.811093	0.030703	
	0.018370	0.810677	0.030322	
	0.015489	0.810309	0.030001	
	0.013052	0.809962	0.029738	
	0.011032	0.809597	0.029534	
	0.009405	0.809170	0.029393	
	0.008160	0.808624	0.029321	
	0.006931	0.806870	0.029455	
	0.000000	0.806870	0.029455	/
4750	0.060032	0.790342	0.036755	
	0.052920	0.788517	0.035819	
	0.046351	0.786900	0.034973	
	0.040332	0.785480	0.034211	
	0.034867	0.784243	0.033530	
	0.029952	0.783175	0.032925	
	0.025577	0.782261	0.032392	
	0.021724	0.781481	0.031927	
	0.018370	0.780814	0.031527	
	0.015489	0.780236	0.031190	
	0.013052	0.779718	0.030913	
	0.011032	0.779225	0.030699	
	0.009405	0.778717	0.030550	
	0.008160	0.778145	0.030474	
	0.006931	0.776563	0.030615	
	0.000000	0.776563	0.030615	/
5000	0.067688	0.769319	0.039240	
	0.060032	0.766754	0.038165	
	0.052920	0.764449	0.037190	
	0.046351	0.762389	0.036308	
	0.040332	0.760562	0.035514	
	0.034867	0.758956	0.034804	
	0.029952	0.757556	0.034172	
	0.025577	0.756346	0.033615	
	0.021724	0.755306	0.033130	
	0.018370	0.754414	0.032711	
	0.015489	0.753646	0.032358	
	0.013052	0.752974	0.032068	
	0.011032	0.752366	0.031844	
	0.009405	0.751785	0.031688	
	0.008160	0.751188	0.031608	
	0.006931	0.749761	0.031756	
	0.000000	0.749761	0.031756	/
5250	0.075907	0.752099	0.041909	
	0.067688	0.748770	0.040674	
	0.060032	0.745753	0.039555	
	0.052920	0.743026	0.038541	
	0.046351	0.740575	0.037623	
	0.040332	0.738388	0.036796	
	0.034867	0.736454	0.036056	
	0.029952	0.734758	0.035398	
	0.025577	0.733283	0.034818	
	0.021724	0.732010	0.034312	
	0.018370	0.730916	0.033876	
	0.015489	0.729978	0.033507	
	0.013052	0.729167	0.033205	
	0.011032	0.728455	0.032970	
	0.009405	0.727807	0.032807	
	0.008160	0.727189	0.032724	
	0.006931	0.725902	0.032877	
	0.000000	0.725902	0.032877	/
5561	0.086997	0.735314	0.045552	
	0.075907	0.729980	0.043737	
	0.067688	0.726132	0.042439	
	0.060032	0.722629	0.041264	
	0.052920	0.719446	0.040198	
	0.046351	0.716570	0.039234	
	0.040332	0.713992	0.038366	
	0.034867	0.711699	0.037589	
	0.029952	0.709679	0.036899	
	0.025577	0.707913	0.036289	
	0.021724	0.706383	0.035758	
	0.018370	0.705066	0.035299	
	0.015489	0.703939	0.034912	
	0.013052	0.702975	0.034594	
	0.011032	0.702147	0.034347	
	0.009405	0.701425	0.034175	
	0.008160	0.700782	0.034088	
	0.006931	0.699651	0.034249	
	0.000000	0.699651	0.034249	/
5750	0.094283	0.727380	0.047988	
	0.086997	0.723547	0.046714	
	0.075907	0.717846	0.044843	
	0.067688	0.713721	0.043505	
	0.060032	0.709956	0.042293	
	0.052920	0.706528	0.041196	
	0.046351	0.703424	0.040203	
	0.040332	0.700633	0.039310	

	0.034867	0.698147	0.038510
	0.029952	0.695950	0.037799
	0.025577	0.694026	0.037172
	0.021724	0.692356	0.036624
	0.018370	0.690917	0.036153
	0.015489	0.689686	0.035754
	0.013052	0.688638	0.035427
	0.011032	0.687746	0.035172
	0.009405	0.686984	0.034995
	0.008160	0.686328	0.034905
	0.006931	0.685283	0.035070
	0.000000	0.685283	0.035070 /
6000	0.104715	0.719356	0.051549
	0.094283	0.713347	0.049580
	0.086997	0.709233	0.048253
	0.075907	0.703096	0.046303
	0.067688	0.698642	0.044910
	0.060032	0.694567	0.043650
	0.052920	0.690846	0.042508
	0.046351	0.687468	0.041477
	0.040332	0.684424	0.040548
	0.034867	0.681705	0.039718
	0.029952	0.679296	0.038980
	0.025577	0.677182	0.038329
	0.021724	0.675342	0.037760
	0.018370	0.673756	0.037270
	0.015489	0.672400	0.036856
	0.013052	0.671250	0.036516
	0.011032	0.670281	0.036252
	0.009405	0.669470	0.036069
	0.008160	0.668797	0.035974
	0.006931	0.667857	0.036146
	0.000000	0.667857	0.036146 /
6250	0.116321	0.714114	0.055618
	0.104715	0.706884	0.053232
	0.094283	0.700528	0.051179
	0.086997	0.696165	0.049795
	0.075907	0.689641	0.047764
	0.067688	0.684896	0.046314
	0.060032	0.680544	0.045003
	0.052920	0.676562	0.043816
	0.046351	0.672940	0.042744
	0.040332	0.669669	0.041780
	0.034867	0.666741	0.040917
	0.029952	0.664142	0.040151
	0.025577	0.661856	0.039475
	0.021724	0.659864	0.038886

	0.018370	0.658145	0.038377
	0.015489	0.656675	0.037948
	0.013052	0.655433	0.037595
	0.011032	0.654394	0.037321
	0.009405	0.653539	0.037131
	0.008160	0.652852	0.037033
	0.006931	0.652008	0.037210
	0.000000	0.652008	0.037210 /
6500	0.129577	0.711829	0.060399
	0.116321	0.702990	0.057416
	0.104715	0.695428	0.054927
	0.094283	0.688763	0.052787
	0.086997	0.684180	0.051345
	0.075907	0.677313	0.049230
	0.067688	0.672306	0.047721
	0.060032	0.667708	0.046357
	0.052920	0.663493	0.045123
	0.046351	0.659652	0.044008
	0.040332	0.656178	0.043007
	0.034867	0.653061	0.042111
	0.029952	0.650291	0.041316
	0.025577	0.647850	0.040615
	0.021724	0.645720	0.040003
	0.018370	0.643881	0.039476
	0.015489	0.642309	0.039031
	0.013052	0.640983	0.038665
	0.011032	0.639881	0.038381
	0.009405	0.638985	0.038183
	0.008160	0.638285	0.038082
	0.006931	0.637528	0.038264
	0.000000	0.637528	0.038264 /
6750	0.145336	0.713043	0.066246
	0.129577	0.701882	0.062343
	0.116321	0.692720	0.059232
	0.104715	0.684862	0.056638
	0.094283	0.677923	0.054407
	0.086997	0.673142	0.052905
	0.075907	0.665968	0.050702
	0.067688	0.660729	0.049132
	0.060032	0.655909	0.047713
	0.052920	0.651485	0.046430
	0.046351	0.647448	0.045273
	0.040332	0.643790	0.044232
	0.034867	0.640504	0.043303
	0.029952	0.637579	0.042478
	0.025577	0.634998	0.041750
	0.021724	0.632744	0.041116

0.018370 0.630795 0.040569
0.015489 0.629130 0.040108
0.013052 0.627728 0.039729
0.011032 0.626569 0.039435
0.009405 0.625637 0.039229
0.008160 0.624925 0.039124
0.006931 0.624248 0.039312
0.000000 0.624248 0.039312 /

7000 0.165526 0.719255 0.073924
0.145336 0.704138 0.068379
0.129577 0.692654 0.064312
0.116321 0.683203 0.061070
0.104715 0.675081 0.058366
0.094283 0.667895 0.056043
0.086997 0.662939 0.054478
0.075907 0.655489 0.052185
0.067688 0.650041 0.050551
0.060032 0.645023 0.049075
0.052920 0.640411 0.047742
0.046351 0.636196 0.046539
0.040332 0.632373 0.045459
0.034867 0.628934 0.044494
0.029952 0.625869 0.043638
0.025577 0.623161 0.042884
0.021724 0.620794 0.042226
0.018370 0.618746 0.041659
0.015489 0.616996 0.041181
0.013052 0.615525 0.040788
0.011032 0.614313 0.040483
0.009405 0.613348 0.040270
0.008160 0.612625 0.040161
0.006931 0.612022 0.040355
0.000000 0.612022 0.040355 /

7250 0.196474 0.735790 0.085890
0.165526 0.711299 0.076315
0.145336 0.695839 0.070542
0.129577 0.684064 0.066306
0.116321 0.674354 0.062930
0.104715 0.665995 0.060115
0.094283 0.658589 0.057695
0.086997 0.653474 0.056066
0.075907 0.645777 0.053680
0.067688 0.640141 0.051980
0.060032 0.634943 0.050446
0.052920 0.630161 0.049060
0.046351 0.625786 0.047810
0.040332 0.621813 0.046689

0.034867 0.618236 0.045687
0.029952 0.615043 0.044799
0.025577 0.612221 0.044017
0.021724 0.609750 0.043335
0.018370 0.607612 0.042748
0.015489 0.605785 0.042252
0.013052 0.604251 0.041845
0.011032 0.602992 0.041529
0.009405 0.601996 0.041309
0.008160 0.601264 0.041195
0.006931 0.600728 0.041395
0.000000 0.600728 0.041395 /

7394 0.252518 0.778592 0.107331
0.196474 0.731686 0.087501
0.165526 0.706949 0.077709
0.145336 0.691307 0.071803
0.129577 0.679379 0.067468
0.116321 0.669532 0.064013
0.104715 0.661047 0.061132
0.094283 0.653524 0.058656
0.086997 0.648325 0.056989
0.075907 0.640497 0.054547
0.067688 0.634760 0.052809
0.060032 0.629467 0.051240
0.052920 0.624595 0.049823
0.046351 0.620135 0.048546
0.040332 0.616082 0.047399
0.034867 0.612431 0.046376
0.029952 0.609170 0.045469
0.025577 0.606286 0.044671
0.021724 0.603761 0.043974
0.018370 0.601574 0.043375
0.015489 0.599706 0.042869
0.013052 0.598138 0.042454
0.011032 0.596853 0.042131
0.009405 0.595841 0.041906
0.008160 0.595104 0.041790
0.006931 0.594605 0.041994
0.000000 0.594605 0.041994 /

7500 0.252518 0.775911 0.108840
0.196474 0.728758 0.088696
0.165526 0.703849 0.078743
0.145336 0.688080 0.072737
0.129577 0.676044 0.068329
0.116321 0.666102 0.064815
0.104715 0.657529 0.061885
0.094283 0.649923 0.059367

0.086997	0.644666	0.057672
0.075907	0.636746	0.055189
0.067688	0.630939	0.053422
0.060032	0.625580	0.051826
0.052920	0.620644	0.050386
0.046351	0.616124	0.049088
0.040332	0.612016	0.047924
0.034867	0.608312	0.046885
0.029952	0.605004	0.045963
0.025577	0.602076	0.045152
0.021724	0.599512	0.044446
0.018370	0.597291	0.043837
0.015489	0.595395	0.043323
0.013052	0.593803	0.042902
0.011032	0.592500	0.042574
0.009405	0.591477	0.042346
0.008160	0.590736	0.042228
0.006931	0.590263	0.042434
0.000000	0.590263	0.042434 /

Table 4 : Sample Eclipse data file used in reservoir simulation - coarse grid rectangular model

```
------------------------------------------------------------------------
------
RUNSPEC
˝

   Coarse grid rectangular model
= NDIVIX NDIVIY NDIVIZ QRDIAL NUMRES QNNCON MXNAQN MXNAQC QDPORO QDPERM
     9      9      1     F      1      F      0      0      F      F
/
= OIL WAT GAS DISGAS VAPOIL QAPITR QWATTR QGASTR NOTRAC NWTRAC NGTRAC
   T   T   T     T      T      F      F      F      0      0      0   /
= UNIT CONVENTION
     'FIELD'                                         /
=  NRPVT  NPPVT  NTPVT NTROCC QROCKC QRCREV
    150     150      1      1      F      T      /
= NSSFUN NTSFUN QDIRKR QREVKR QVEOP QHYST QSCAL QSDIR QSREV NSEND NTEND
   100      1      F      T     F     F     F     F     T     1     1 /
= NDRXVD NTEQUL NDPRVD QUIESC QTHPRS QREVTH QMOBIL NTTRVD NSTRVD
    10      1    100      F      F      T      F      1      1  /
=  NTFIP QGRAID  QPAIR
     1      F      F                                /
= NWMAXZ NCWMAX NGMAXZ NWGMAX
     2      70     2     2                          /
= QIMCOL NWFRIC NUPCOL
     F      0      20                                /
= MXMFLO MXMTHP MXMWFR MXMGFR MXMALQ NMMVFT
     0      0      0      0      0      0      /
= MXSFLO MXSTHP NMSVFT MXCFLO MXCWOC MXCGOC NCRTAB
     0      0      0      0      0      0      0  /
= NAQFET NCAMAX
     0      0                                   /
=   DAY   MONTH  YEAR
     1    'JAN'  1993                           /
= QSOLVE NSTACK QFMTOU QFMTIN QUNOUT QUNINP
     T     200     F        F     F      F      /

GRID    ================================================================
-------- IN THIS SECTION , THE GEOMETRY OF THE  SIMULATION GRID AND THE
-------- ROCK PERMEABILITIES AND POROSITIES ARE DEFINED.
------------------------------------------------------------------------
-- OLDTRAN  using block centered transmisibilities
---OLDTRAN

---NEWTRAN
INIT

EQUALS             I1 I2  J1 J2  K1 K2
'TOPS'    7000     1   9   1  9   1 1 /
'DX'      295.5                       /
'DY'      295.32                      /
'DZ'      100                         /
'PERMX'   5                           /
'PERMY'   5                           /
'PERMZ'   5                           /
'PORO'    0.30                        /
/

PROPS    ===============================================================
-------- THE PROPS SECTION DEFINES THE REL. PERMEABILITIES, CAPILLARY
```

```
-------- PRESSURES, AND THE PVT PROPERTIES OF THE RESERVOIR FLUIDS
------------------------------------------------------------------------

-- PVT PROPERTIES AS GIVEN IN TABLE 2
"
INCLUDE
"
RICHPVT.DATA  /
"

"
-- WATER PROPERTIES
"
--    REF. PRES  WATER  COMPRESSI-     VISCOSITY   VISCOSIBILITY
--               FVF     BILITY
PVTW
        5400     1.0    2.67E-6          0.5            0.0
/

-- ROCK COMPRESSIBILITY
--   REF. PRES   COMPRESSIBILITY
ROCK
        5400        5.0E-06  /

-- RELATIVE PERMEABILITY DATA
INCLUDE
RELPERM.DATA  /

-- SWITCH ON OUTPUT OF ALL PROPS DATA
RPTPROPS
  0  1 1 0 0 0 0 0 1/

--REGIONS
================================================================
--RPTREGS

SOLUTION ===============================================================
-------- THE SOLUTION SECTION DEFINES THE INITIAL STATE OF THE SOLUTION
-------- VARIABLES (PHASE PRESSURES, SATURATIONS AND GAS-OIL RATIOS)
------------------------------------------------------------------------
-- DATA FOR INITIALISING FLUIDS TO POTENTIAL EQUILIBRIUM
-- INITIAL RESERVOIR PRESSURE
--
--   DATUMD PRES   WOC  PCWOC  GOC   PCGOC   OIL COMP SPECIFIED AT GOC
EQUIL
      7050   7500  15000  0.0  5000   0.0      1          1 /

--INITIAL RS IN GRIDBLOCKS
RSVD
1000  1.677083
10000 1.677083
/

RVVD
1000  0.086997
10000 0.086997
/
-- OUTPUT CONTROLS (SWITCH ON OUTPUT OF INITIAL GRID BLOCK PRESSURES)
RPTSOL
  1  1  1  1  1  1  0  1  0   1  1  12*0 4*1 /

SUMMARY  ===============================================================
-------- THIS SECTION SPECIFIES DATA TO BE WRITTEN TO THE SUMMARY FILES
-------- AND WHICH MAY LATER BE USED WITH THE ECLIPSE GRAPHICS PACKAGE
```

```
------------------------------------------------------------------------
--REQUEST OUTPUT OF THE SUMMARY FILE DATA AT THE END OF THE NORMAL
--ECLIPSE PRINTED OUTPUT
--RUNSUM

SEPARATE

-- OIL PRODUCTION RATE
FOPR

-- OIL PRODUCTION RATE
FGPR

-- GOR  FOR FIELD
FGOR

-- CUMMULATIVE OIL PRODUCTION
FOPT

-- CUMMULATIVE OIL PRODUCTION
FGPT

-- FIELD OIL RECOVERY NOT AVAILABLE FOR ECL 300
FOE

-- FIELD PRESSURE
FPR

-- BOTTOM HOLE PRESSURE FOR ALL WELLS
WBHP
PRODUCER /

SCHEDULE ===============================================================
-------- THE SCHEDULE SECTION DEFINES THE OPERATIONS TO BE SIMULATED
------------------------------------------------------------------------
-- CONTROLS ON OUTPUT AT EACH REPORT TIME
--TSCRIT
--0.5 1* 10 /
RPTSCHED
   1   1   1   1   1   0   2   0   0   0
   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   1   1   1
   0   0   0   /


-- CONTROLS ON OUTPUT
--RPTPRINT
-- 3  0  1  0  0  2  /

-- CONTROLS ON OUTPUT
--RPTPRINT
--1 1 1 1 1 1 1 1 0 1 /


-- WELL SPECIFICATION DATA
--
--     WELL     GROUP LOCATION  BHP     PI
--     NAME     NAME    I  J   DEPTH   DEFN
WELSPECS
--  INJECTOR   G    1  1    12900   GAS  /
    PRODUCER   G    5  5    7050    GAS  /
/
```

```
-- COMPLETION SPECIFICATION DATA
--
--     WELL        -LOCATION-  OPEN/ SAT CONN   WELL
--     NAME        I  J K1 K2  SHUT  TAB FACT   DIAM
COMPDAT
--  INJECTOR    1  1  1 63 OPEN    0   -1   0.5833  /
    PRODUCER    5  5  1 1  OPEN    0   -1   0.7  /
/

-- PRODUCTION WELL CONTROLS
--
--      WELL     OPEN/  CNTL   OIL  WATER   GAS  LIQU   RES   THP
--      NAME     SHUT   MODE  RATE   RATE  RATE  RATE  RATE
WCONPROD
   PRODUCER      OPEN   OIL   1095   1*     1*   1*     1*    500/
/

-- ECONOMIC LIMIT DATA FOR PRODUCTION WELLS
--
--      WELL      MIN   MIN  MAX   MAX  MAX  WORK-
--      NAME      QO    QG   WC    GOR  WGR  OVER
WECON
      PRODUCER .1 5* 'Y' /
/
-- NEWTON ITERATIONS MAX 50
TUNING
1* 10 0.001 0.0015 2.0 0.005 0.001 1.1/
8* 0.000001  /
30 3 5000 1* 30 /
TSTEP
30 60 60 210 5*3650
/
END     ================================================================
```

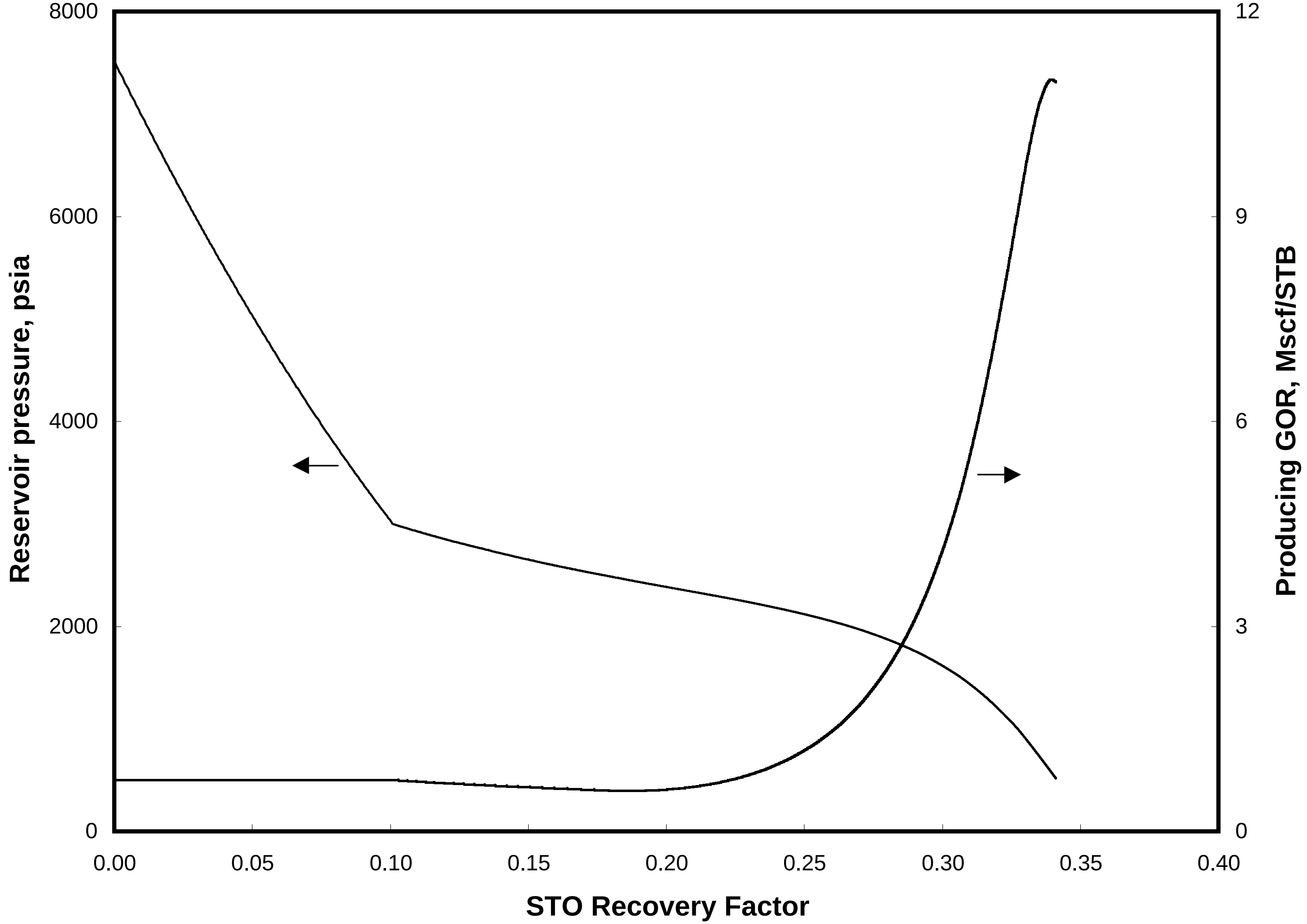

8000
6000
4000
2000
0
Reservoir pressure, psia
12
9
6
3
0
Producing GOR, Mscf/STB
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
STO Recovery Factor

Fig. 1

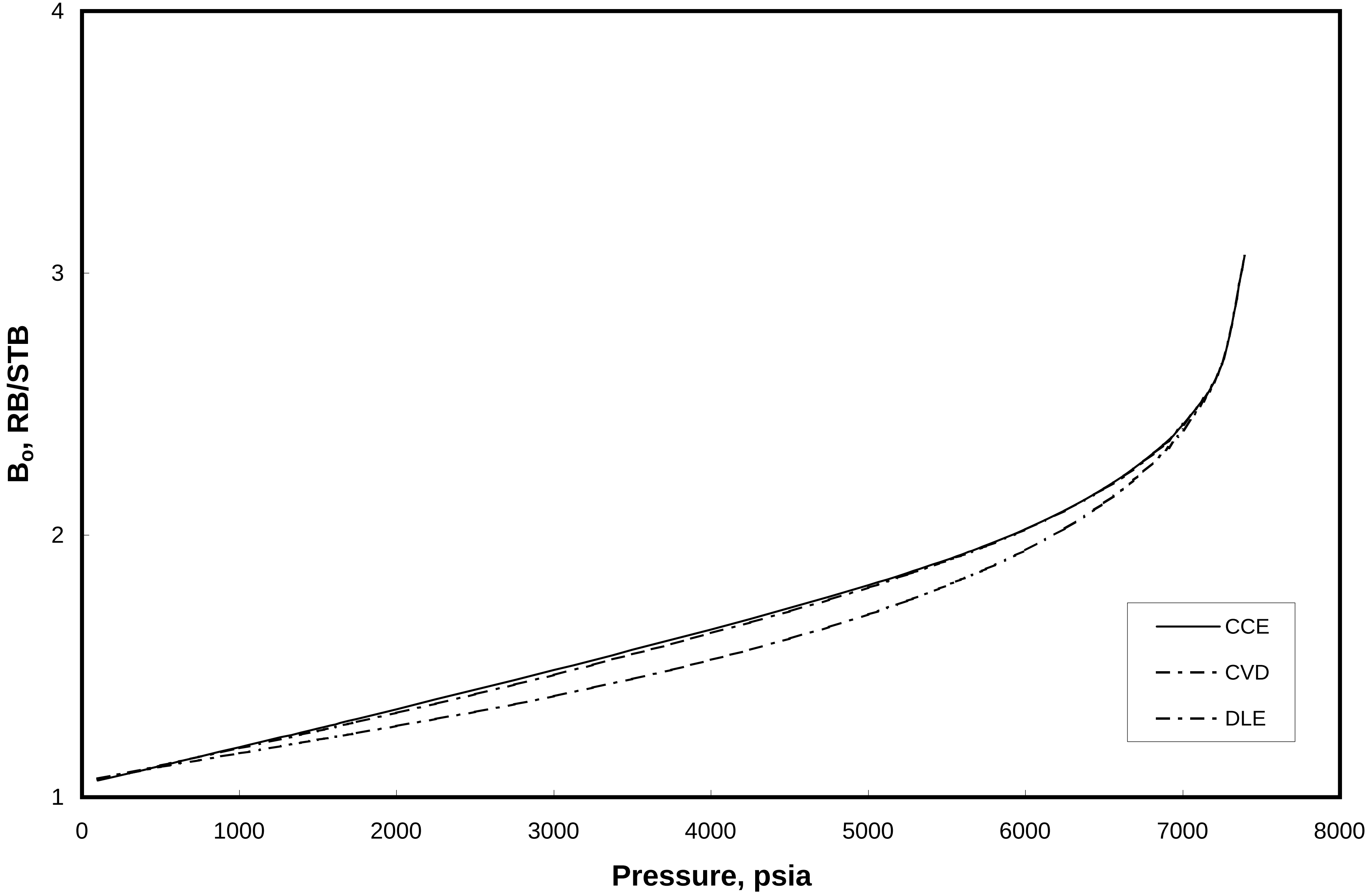
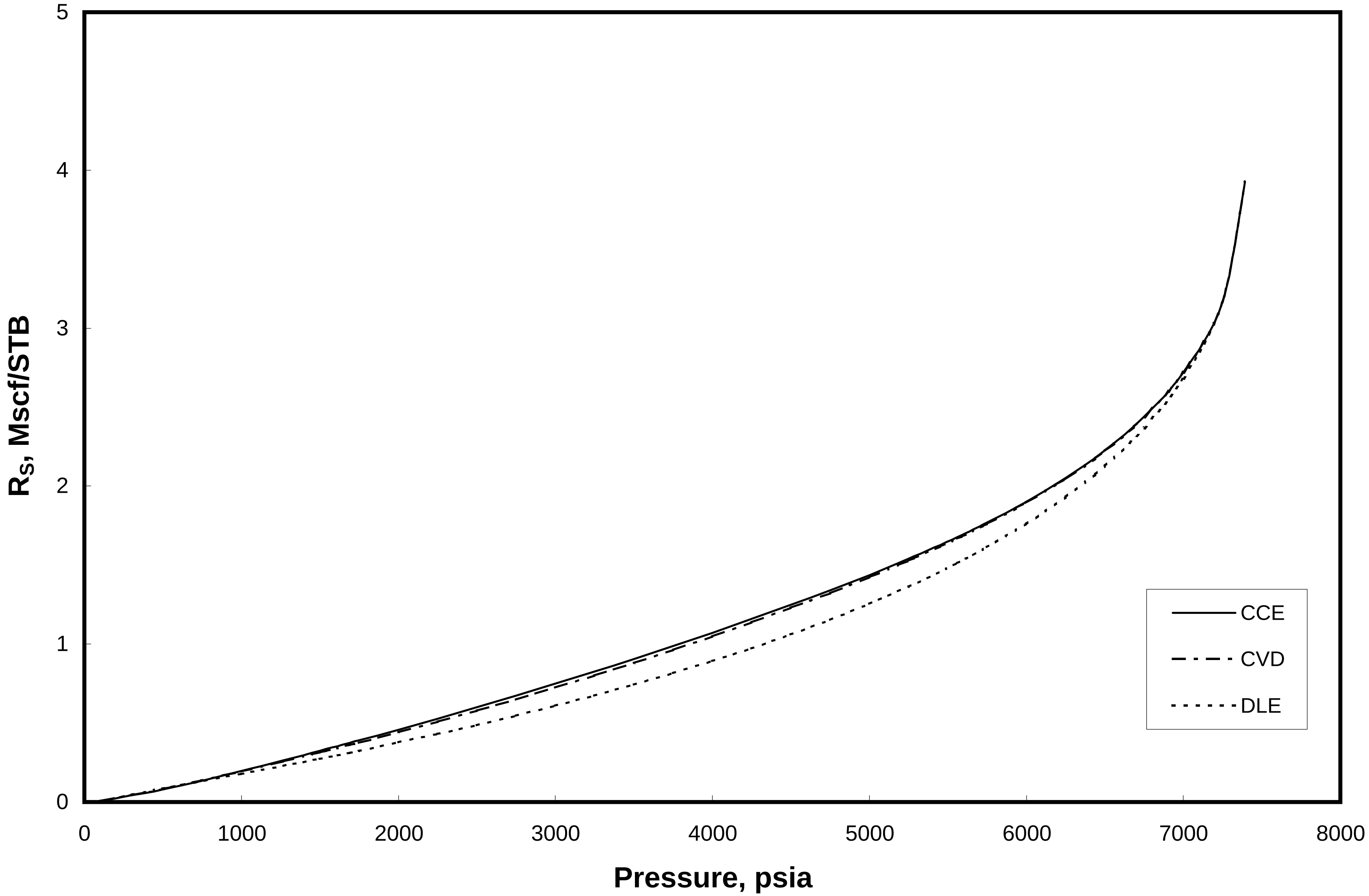
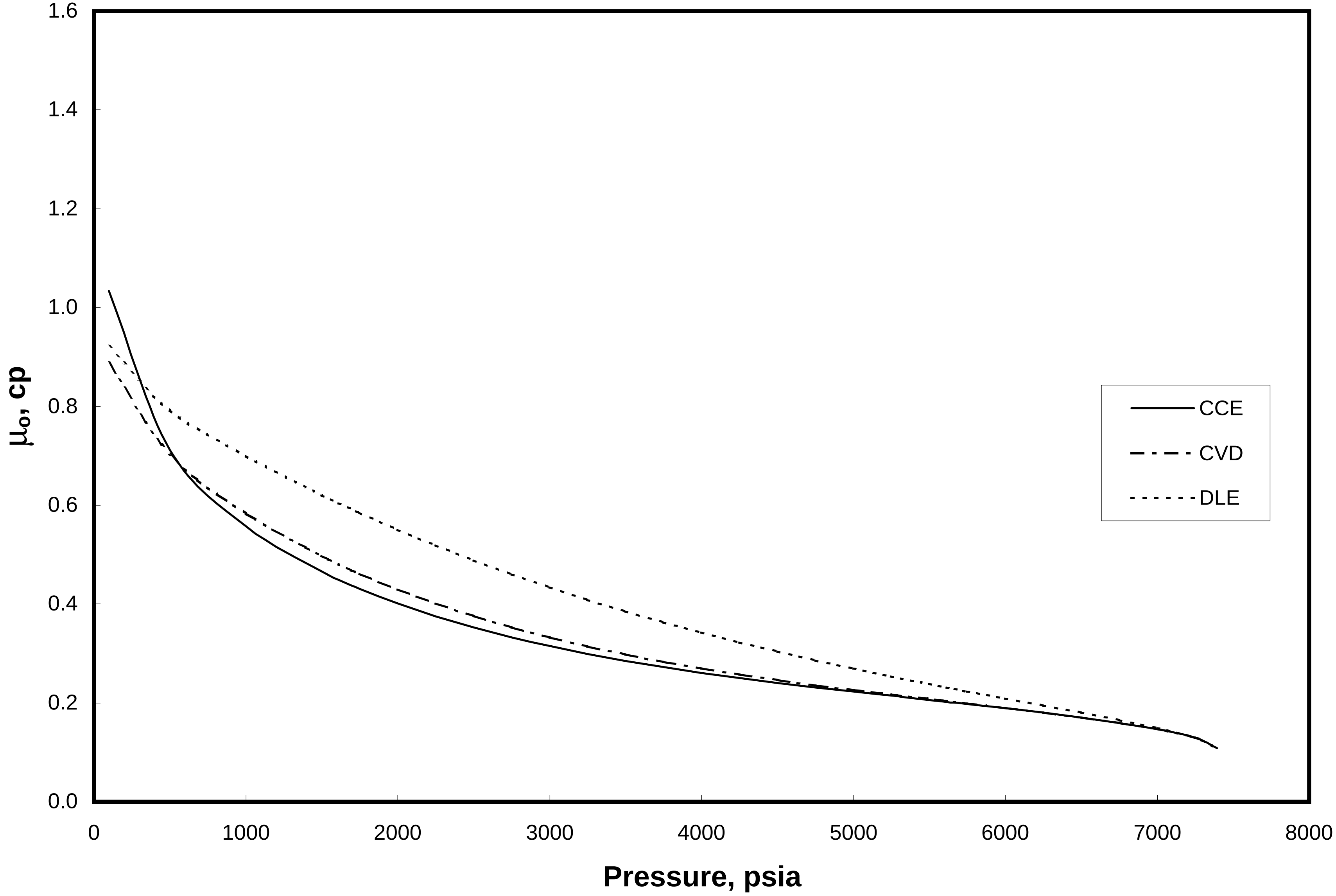

4
3
2
1
0
1000
2000
3000
4000
5000
6000
7000
8000
Pressure, psia
B$_o$, RB/STB
CCE
CVD
DLE

Fig. 2



5
4
3
2
1
0
R_S, Mscf/STB
0
1000
2000
3000
4000
5000
6000
7000
8000
Pressure, psia
CCE
CVD
DLE

Fig. 3



1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
μ_o, cp
Pressure, psia
CCE
CVD
DLE

Fig. 4

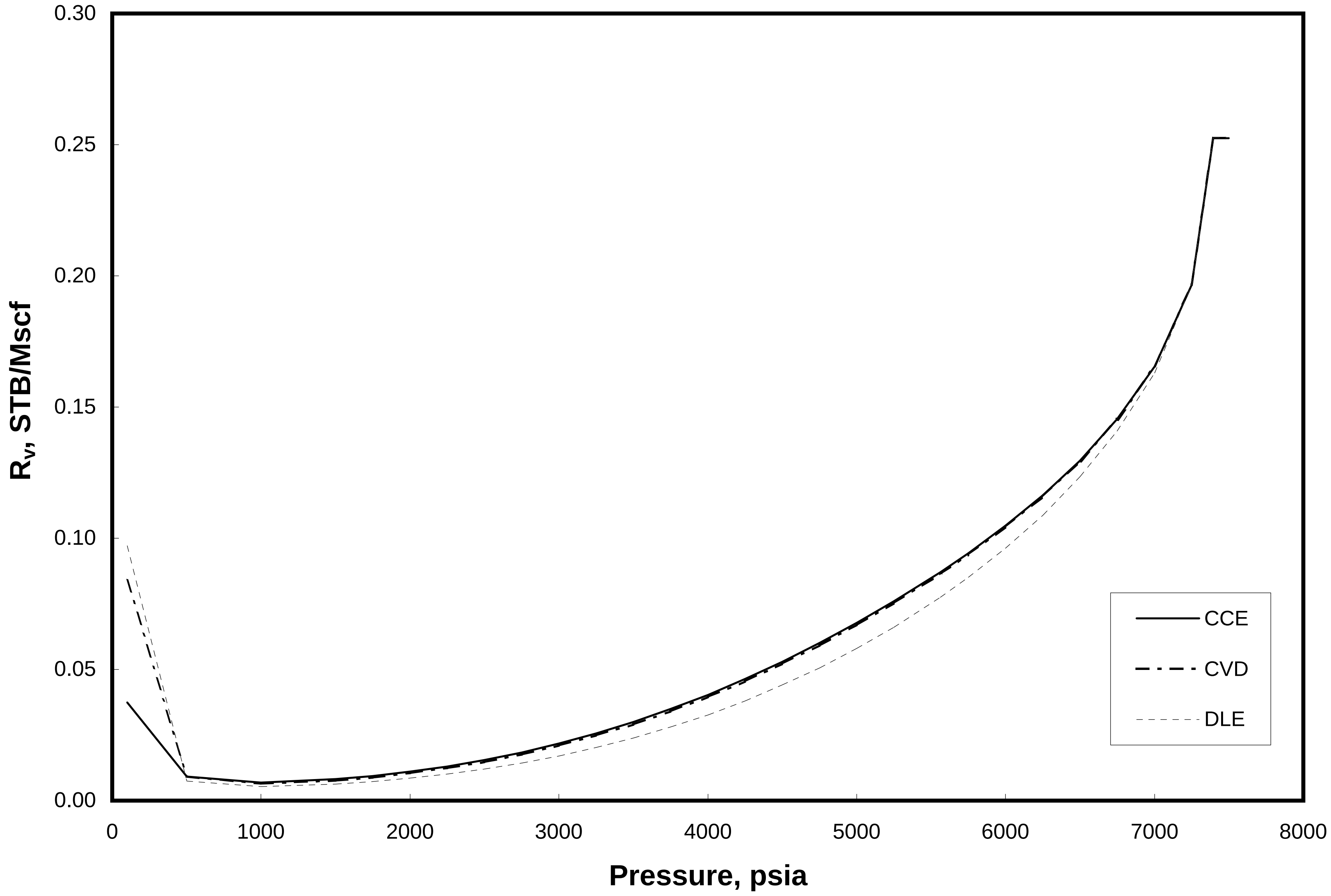

0.30
0.25
0.20
0.15
0.10
0.05
0.00
R_v, STB/Mscf
0
1000
2000
3000
4000
5000
6000
7000
8000
Pressure, psia
CCE
CVD
DLE

Fig. 5

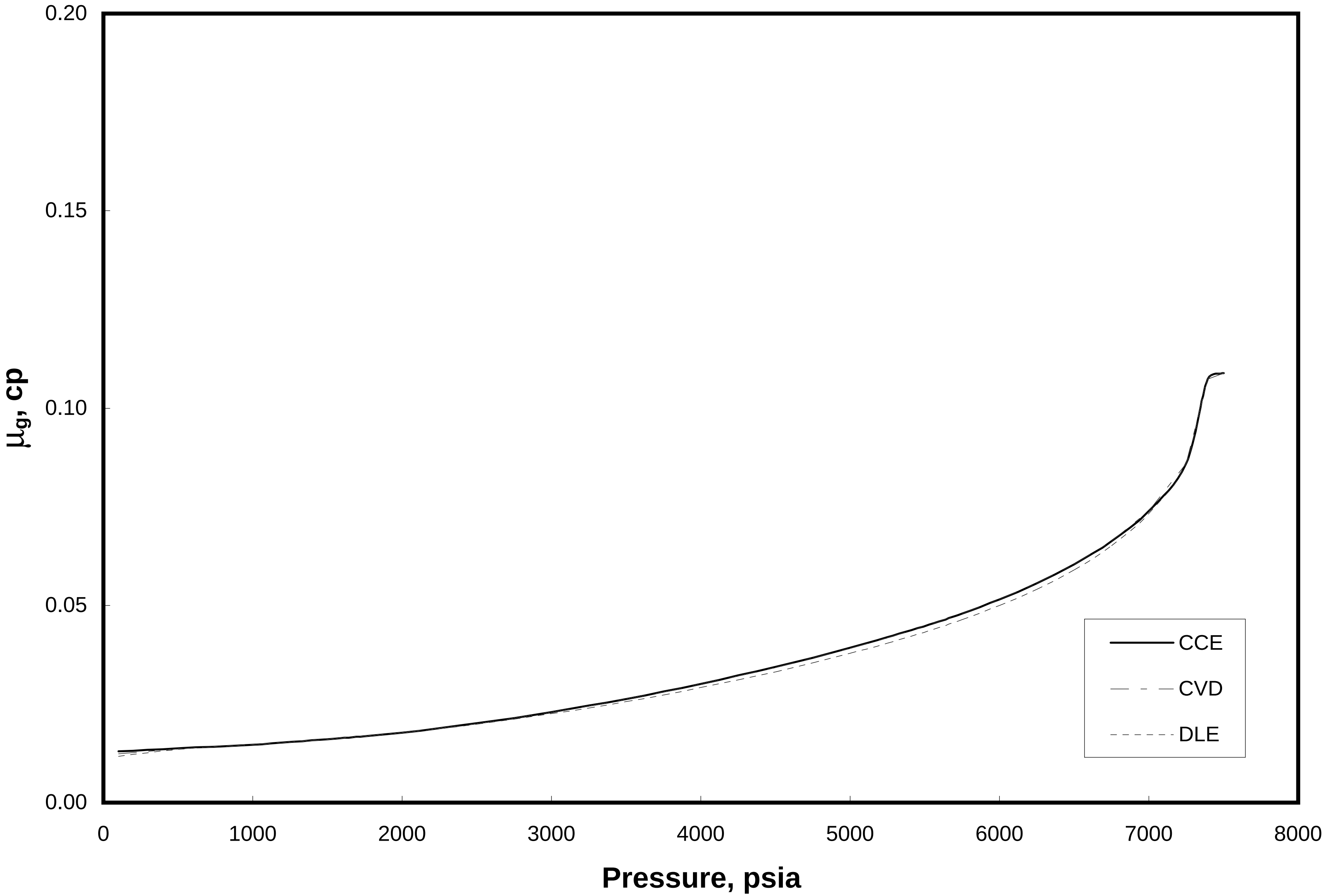

0.20
0.15
0.10
0.05
0.00
μ_g, cp
0
1000
2000
3000
4000
5000
6000
7000
8000
Pressure, psia
CCE
CVD
DLE

Fig. 6

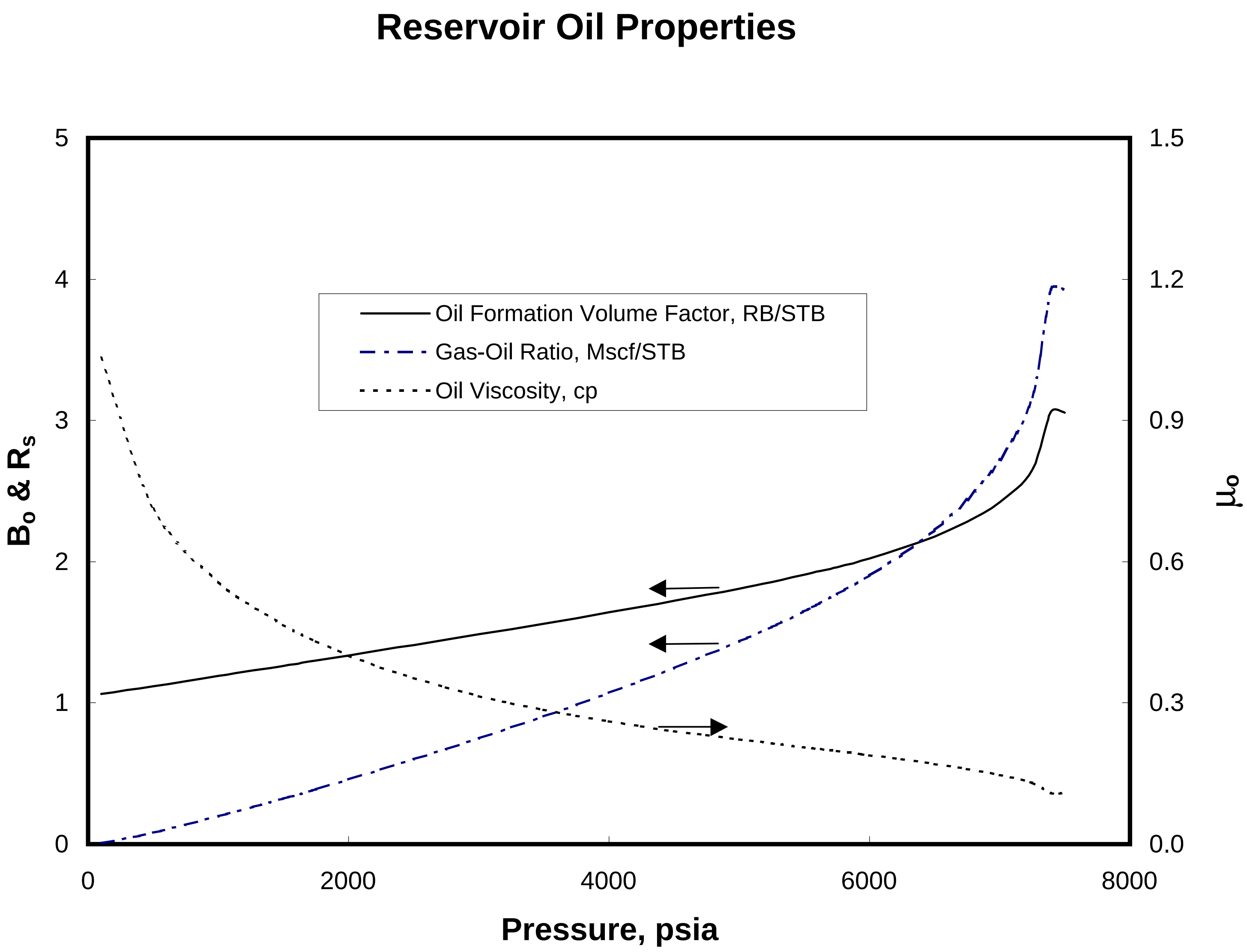

Reservoir Oil Properties
Oil Formation Volume Factor, RB/STB
Gas-Oil Ratio, Mscf/STB
Oil Viscosity, cp
Bo & Rs
μo
Pressure, psia
0
1
2
3
4
5
0.0
0.3
0.6
0.9
1.2
1.5
0
2000
4000
6000
8000

Fig. 7

Reservoir Gas Properties

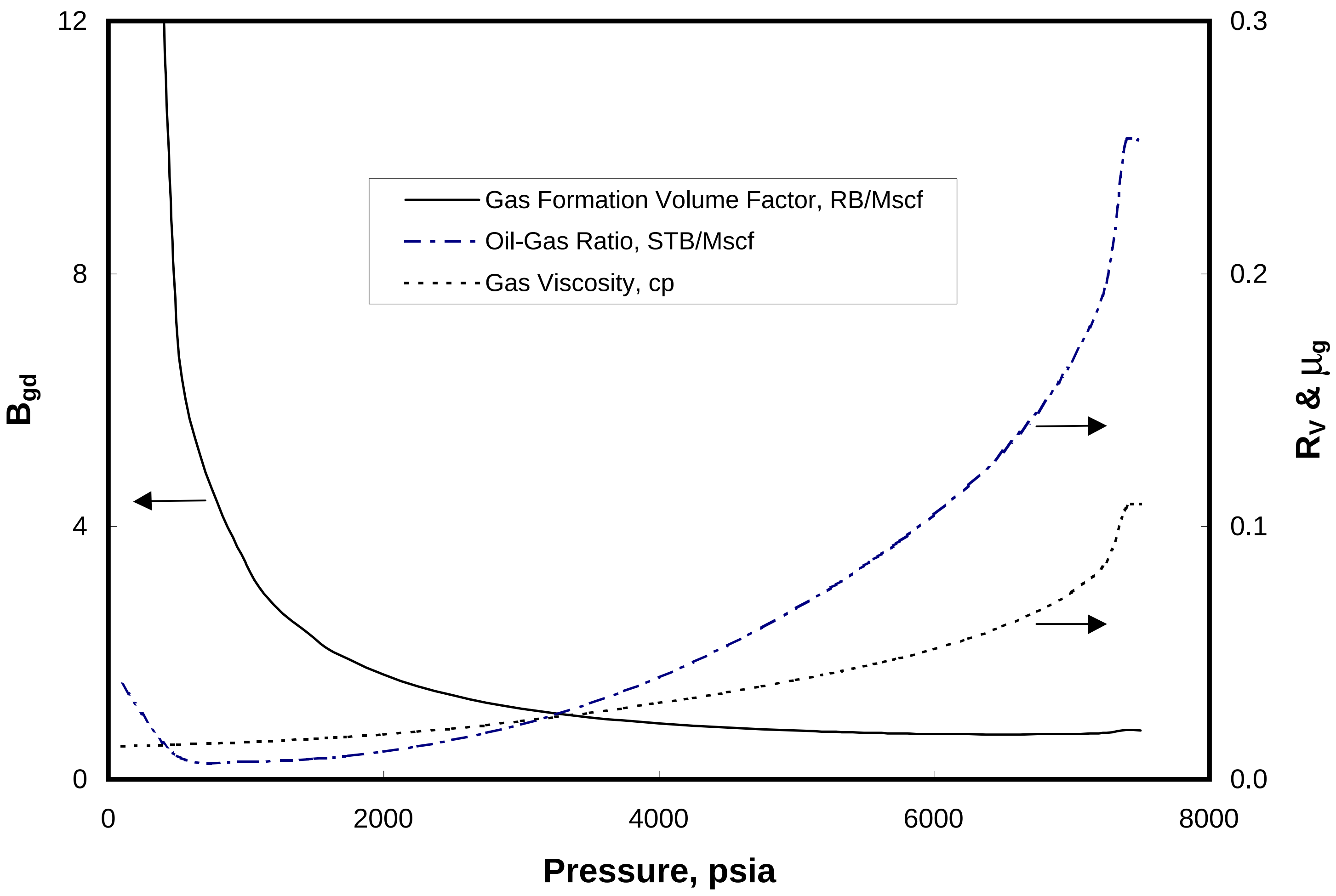


Fig. 8

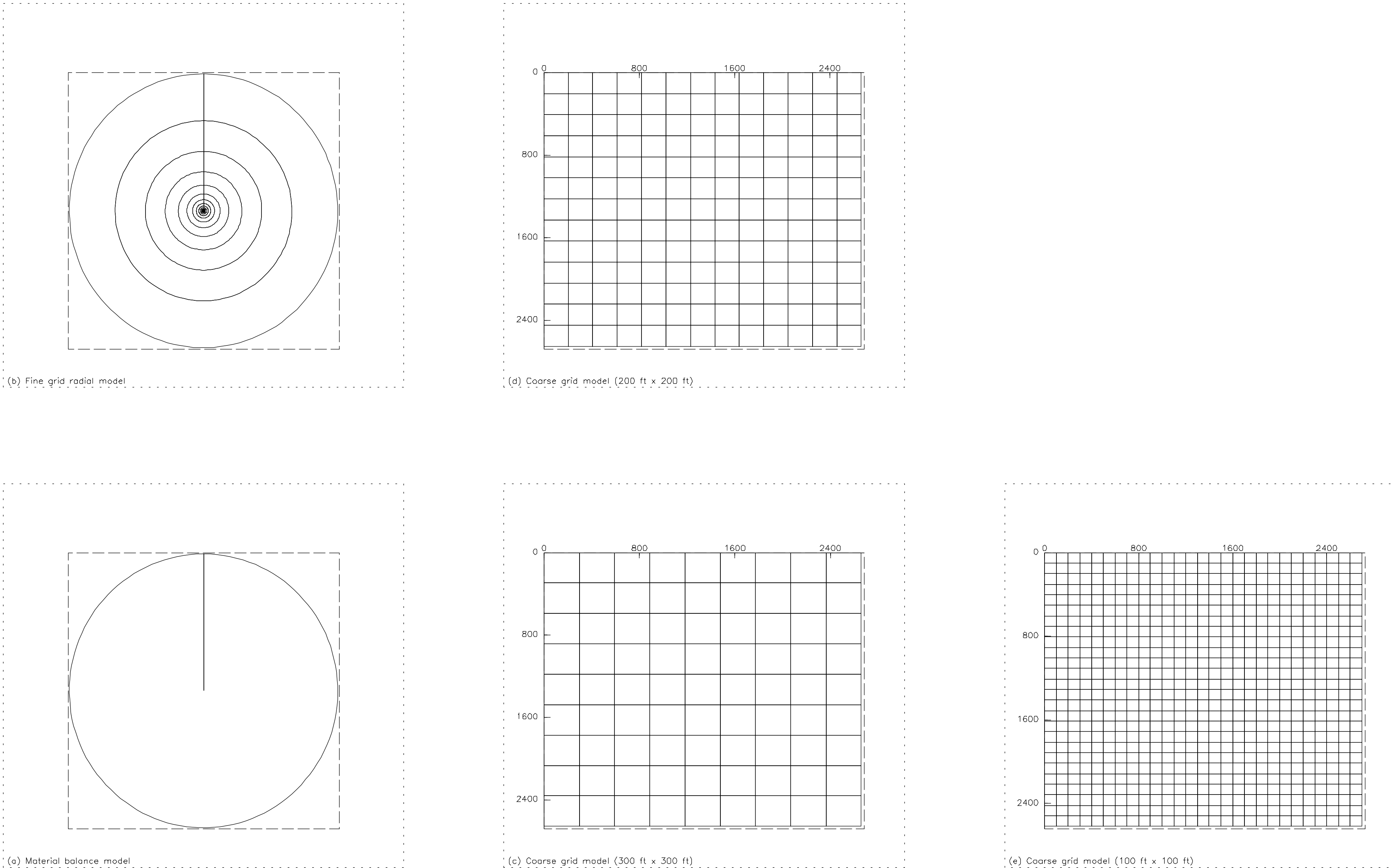


Fig. 9 Reservoir Simulation Models

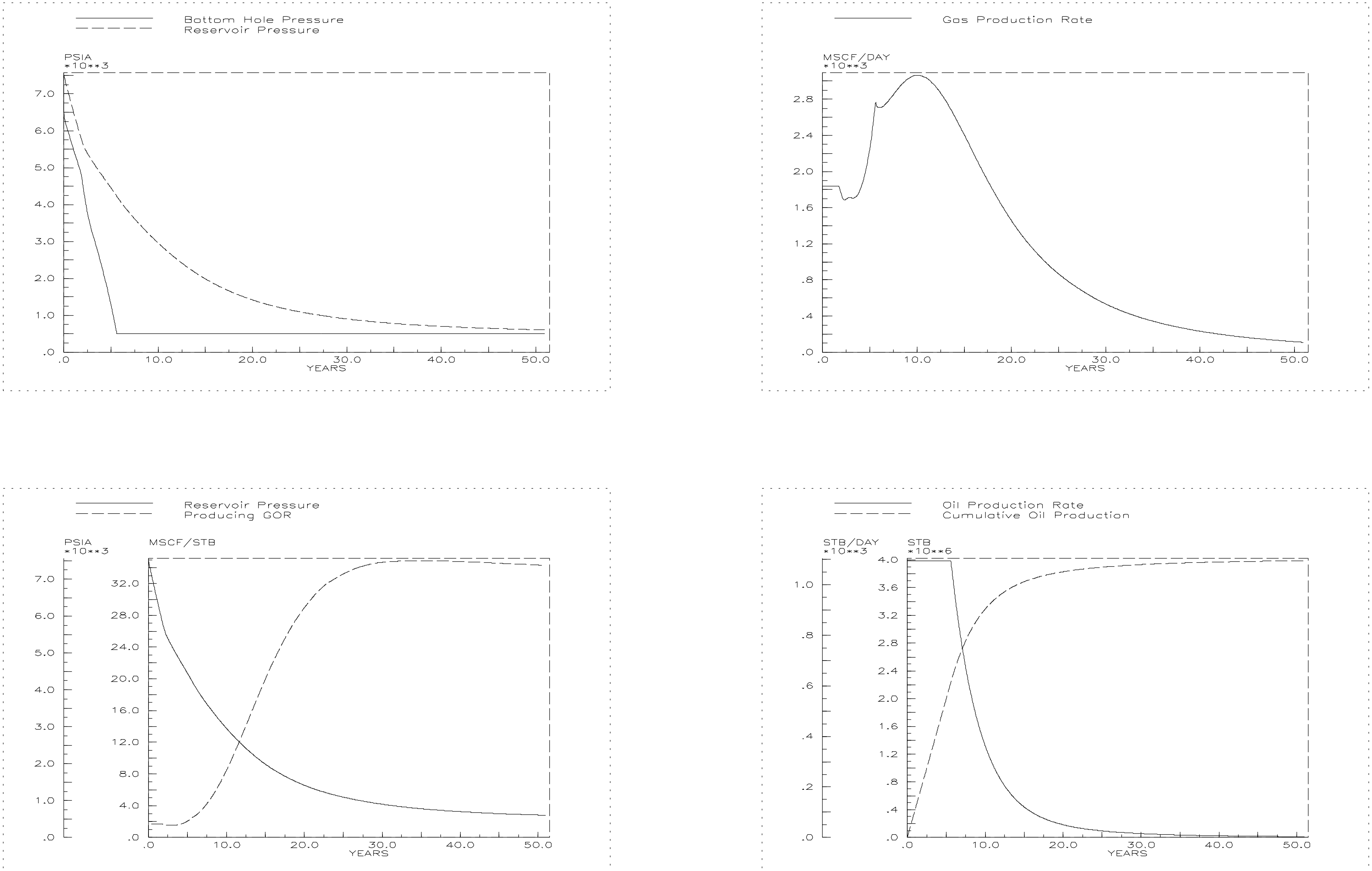


Fig. 10 Reservoir Performance of a Depletion Drive Reservoir

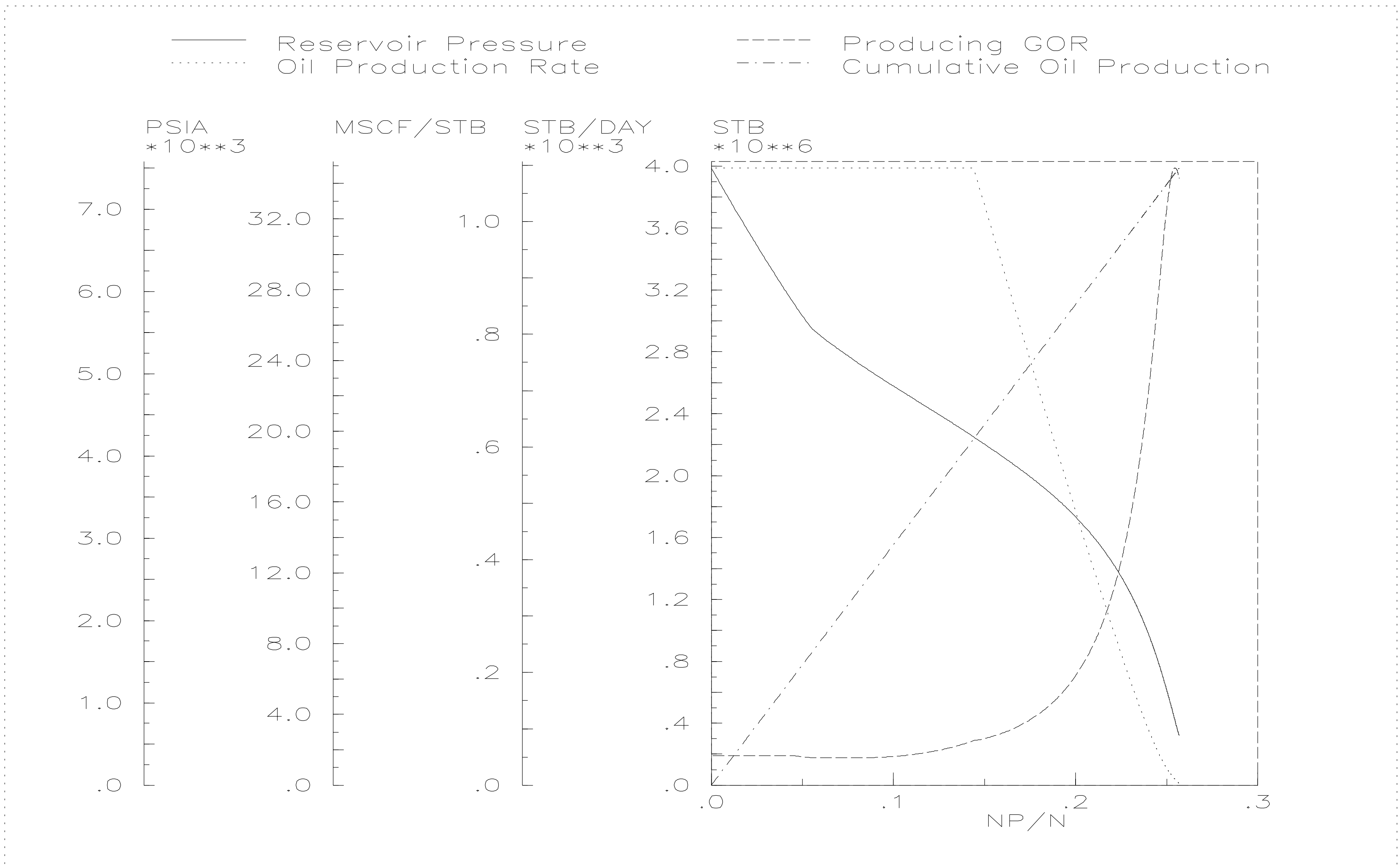


Fig. 11 Reservoir Performance of a Depletion Drive reservoir

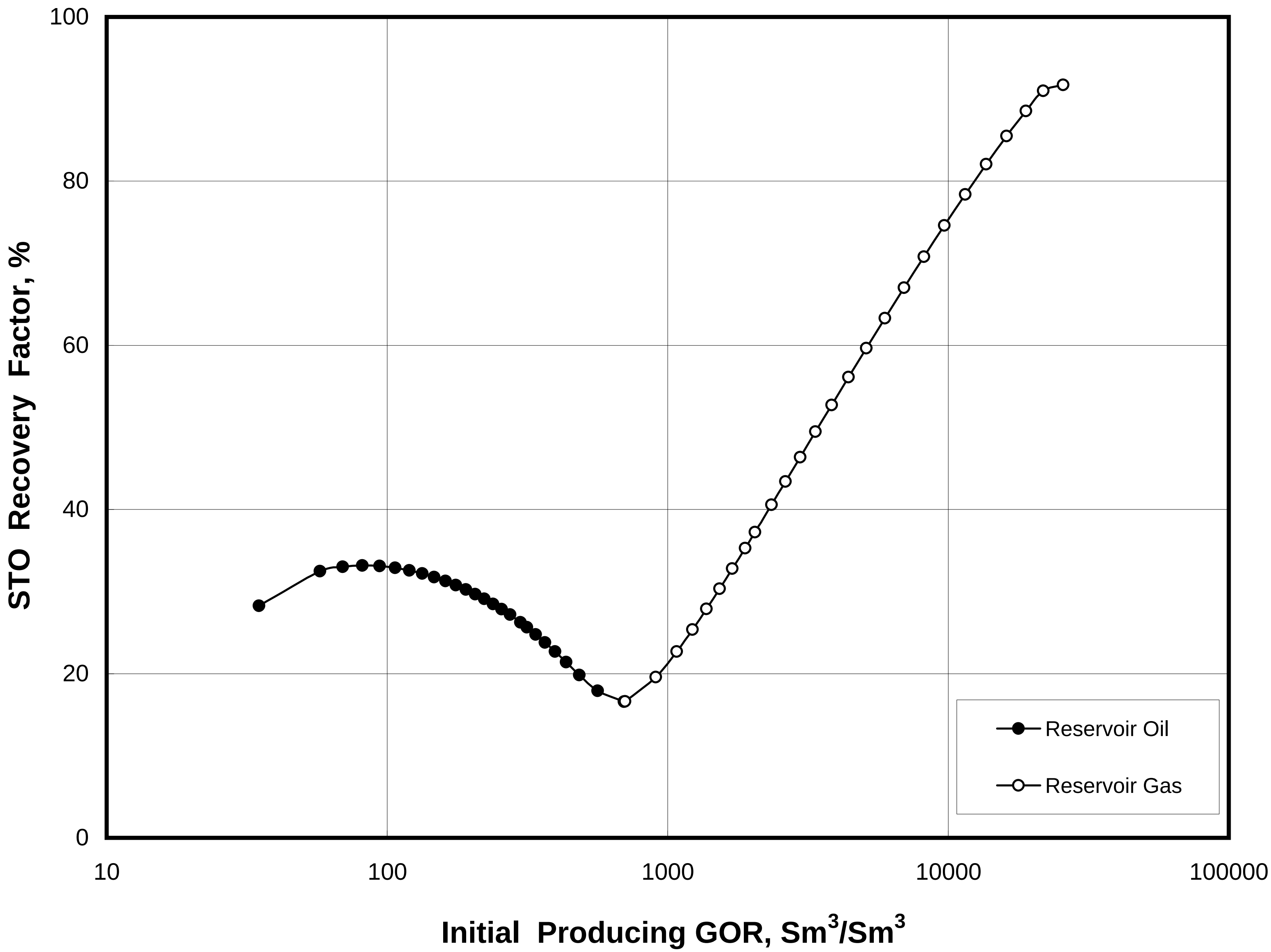

100
80
60
40
20
0
STO Recovery Factor, %
10
100
1000
10000
100000
Initial Producing GOR, Sm3/Sm3
Reservoir Oil
Reservoir Gas

Fig. 12

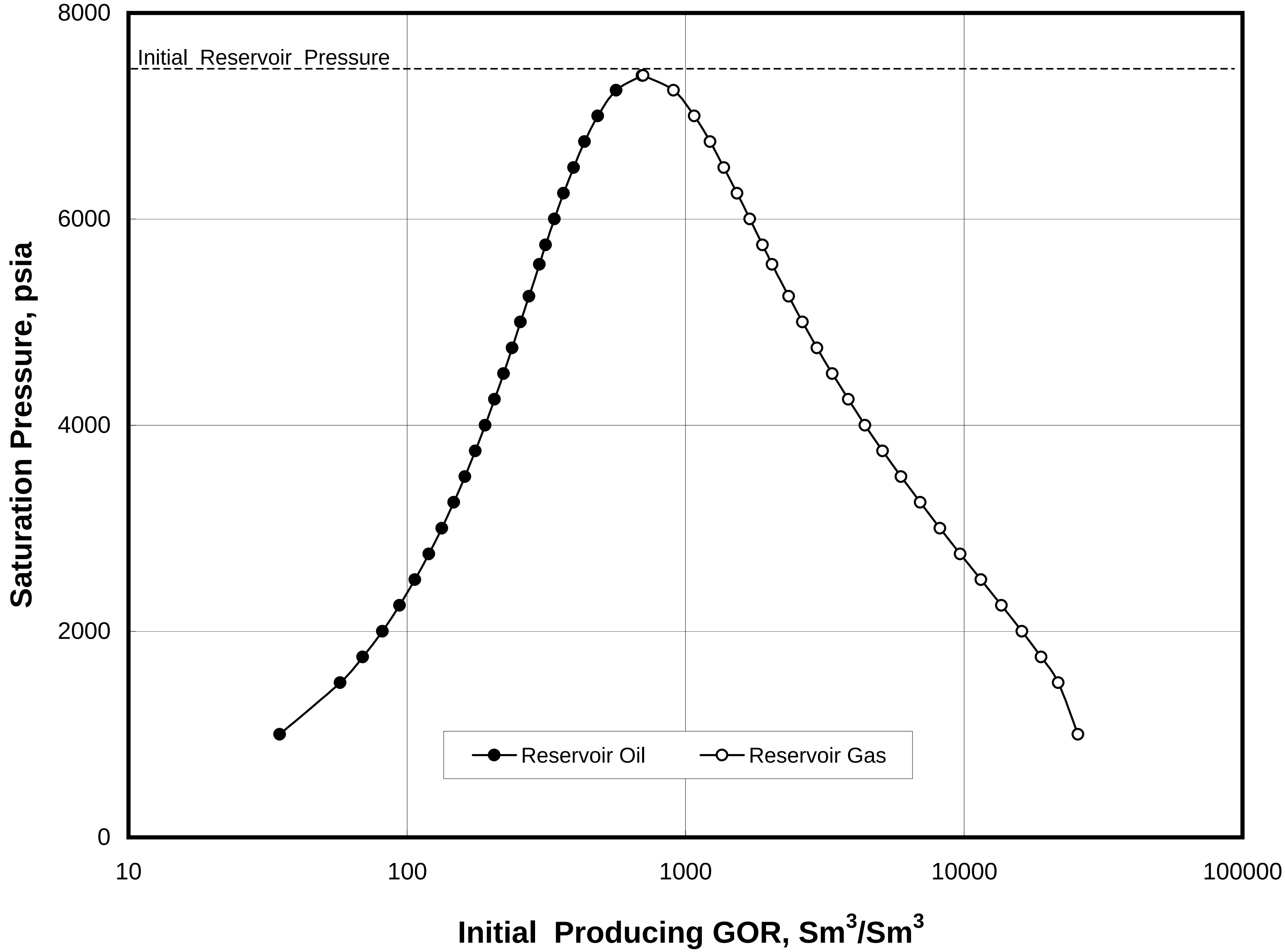

Saturation Pressure, psia
8000
6000
4000
2000
0
Initial Reservoir Pressure
Reservoir Oil
Reservoir Gas
10
100
1000
10000
100000
Initial Producing GOR, Sm3/Sm3

Fig. 13

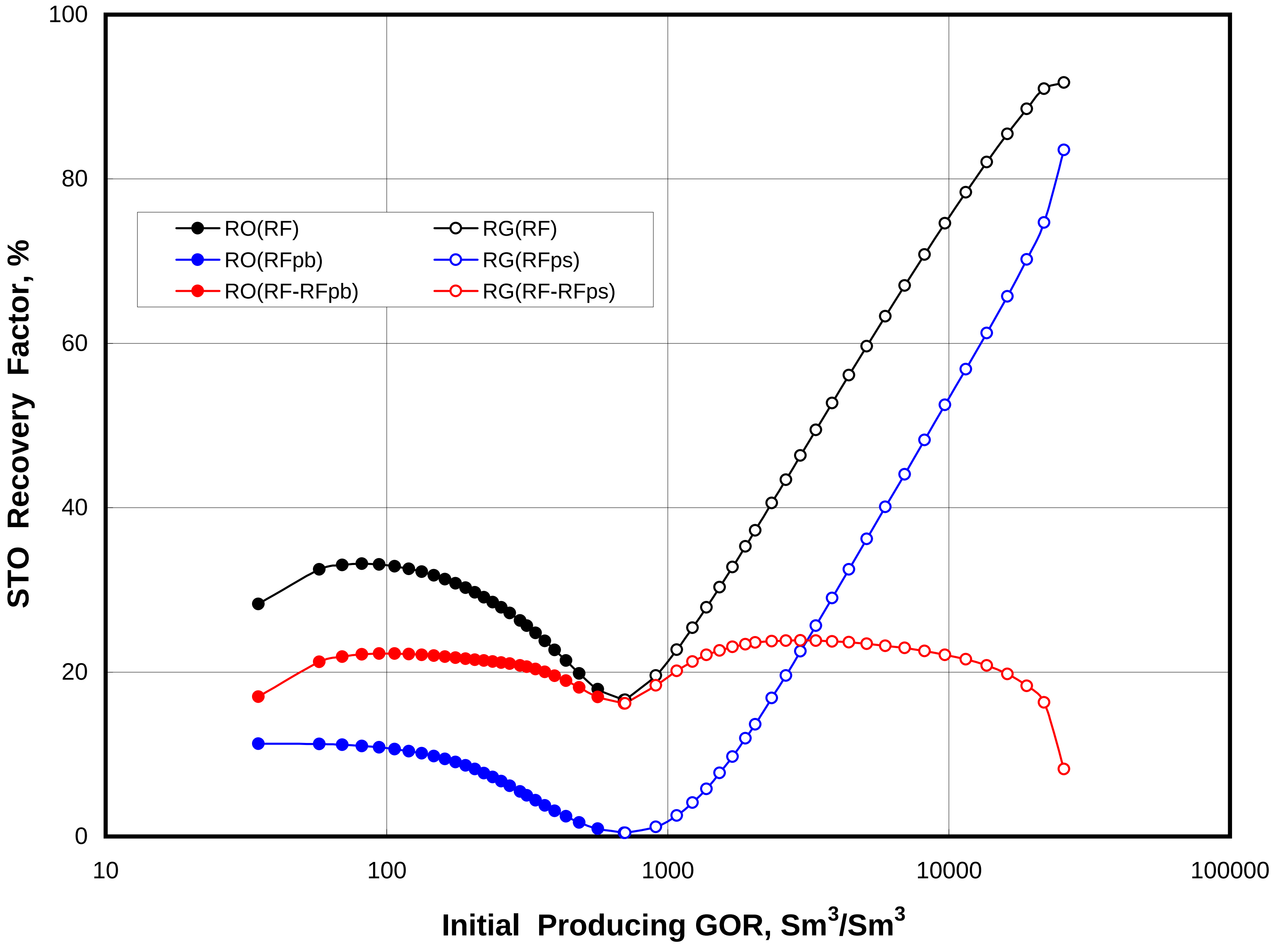

100
80
60
40
20
0
STO Recovery Factor, %
RO(RF)
RO(RFpb)
RO(RF-RFpb)
RG(RF)
RG(RFps)
RG(RF-RFps)
10
100
1000
10000
100000
Initial Producing GOR, Sm3/Sm3

Fig. 14

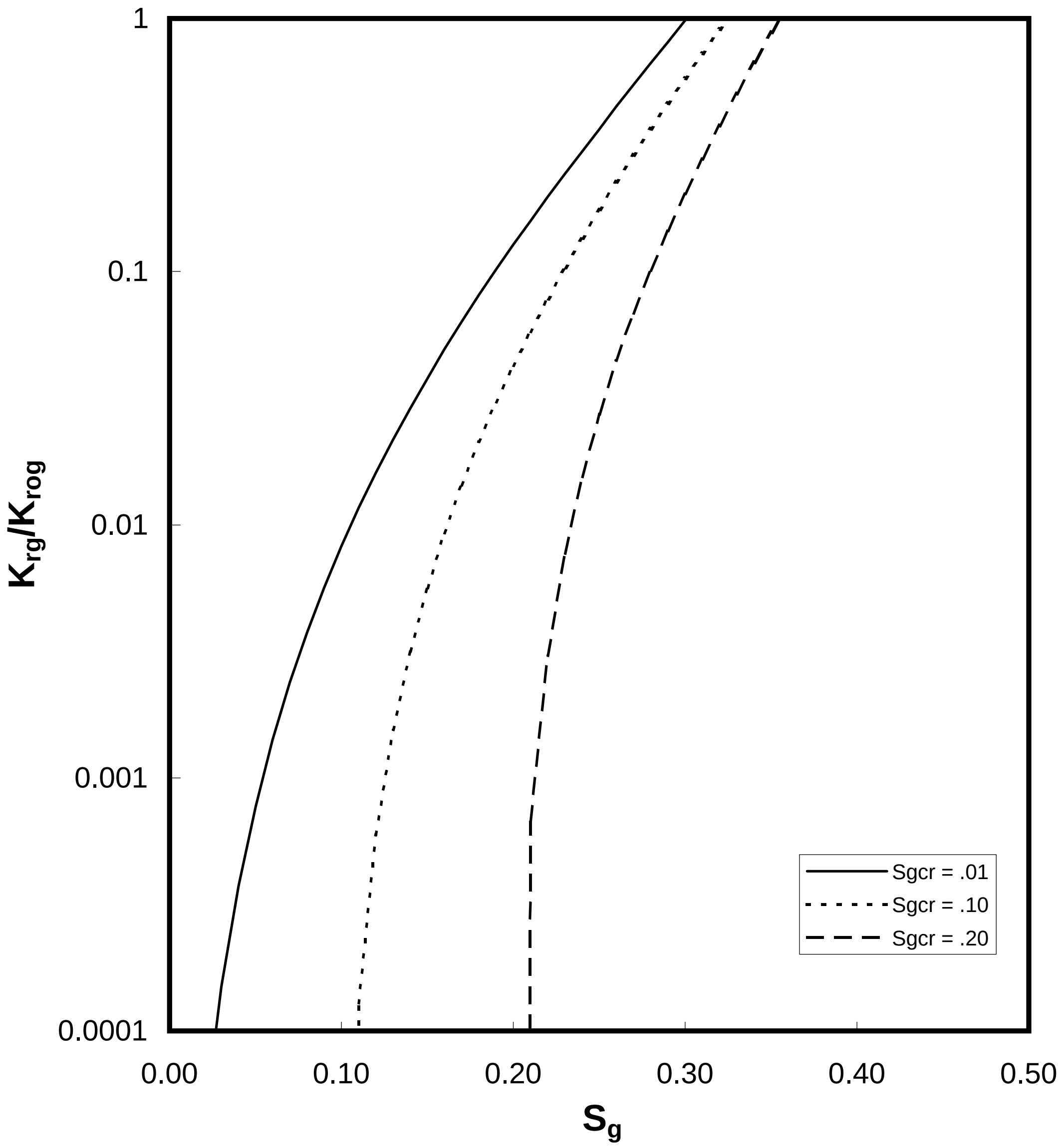

1
0.1
0.01
0.001
0.0001
0.00
0.10
0.20
0.30
0.40
0.50
K_{rg}/K_{rog}
S_g
Sgcr = .01
Sgcr = .10
Sgcr = .20

Fig. 15

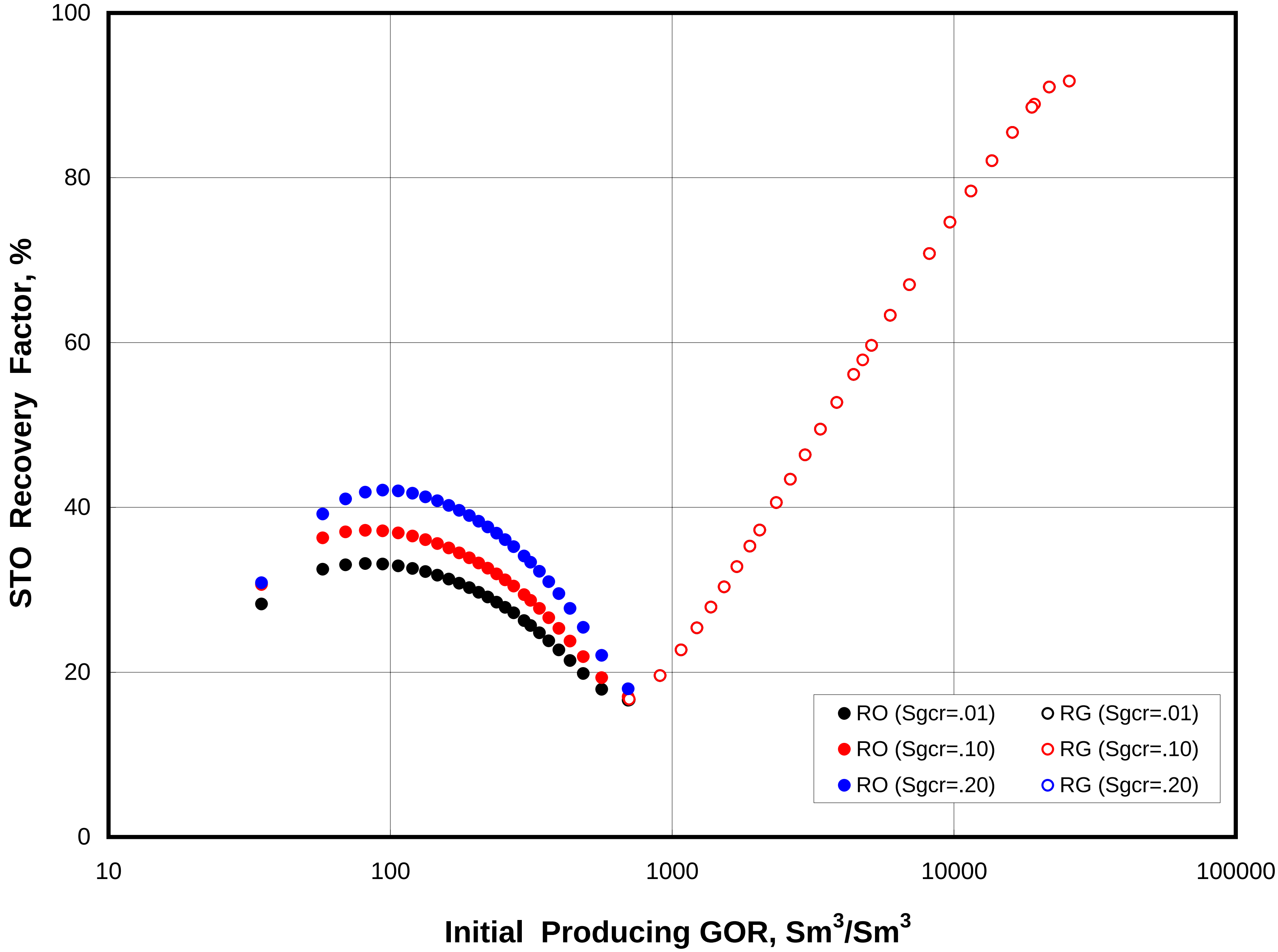
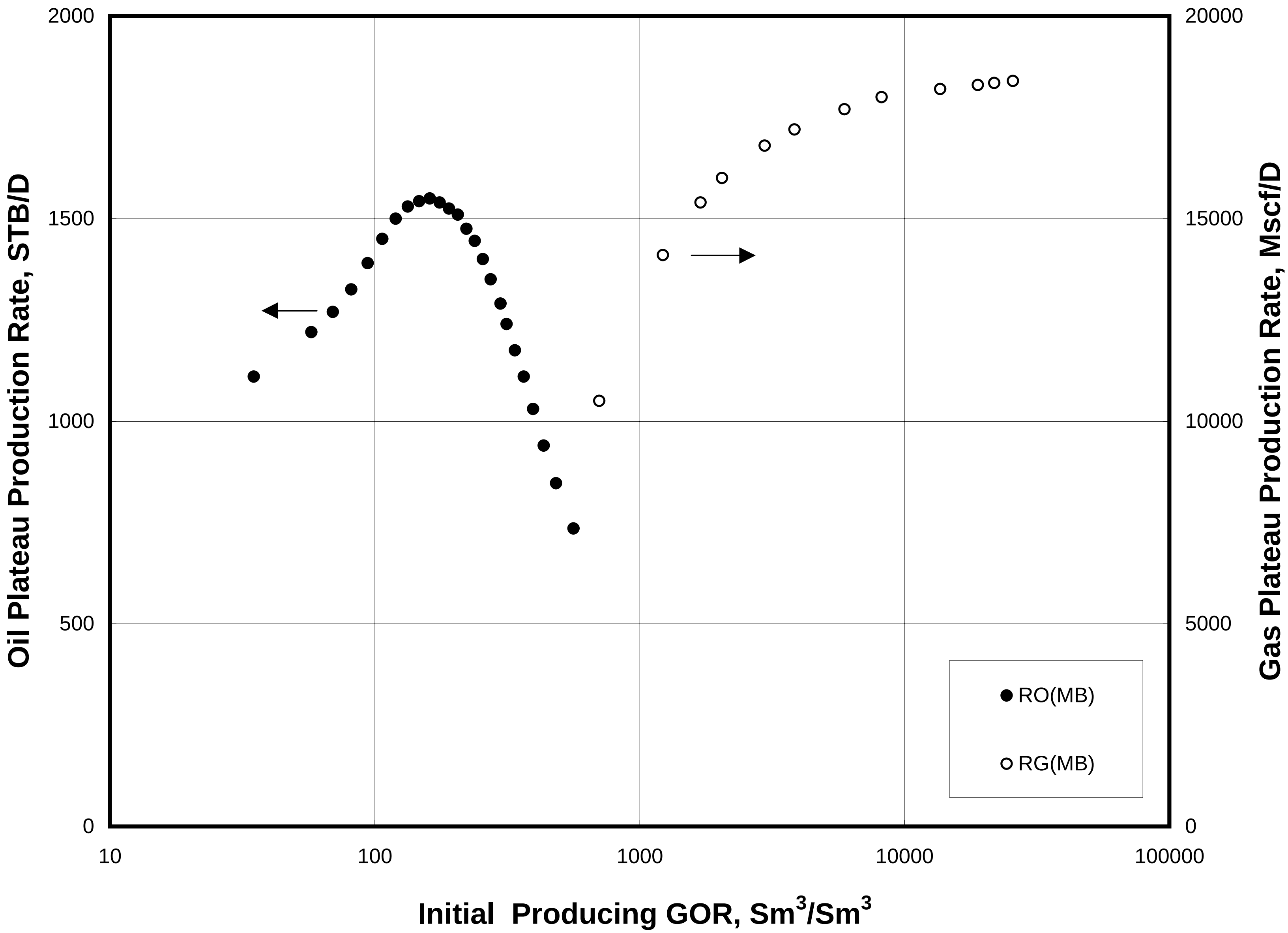

100
80
60
40
20
0
10
100
1000
10000
100000
STO Recovery Factor, %
Initial Producing GOR, Sm3/Sm3
RO (Sgcr=.01)
RG (Sgcr=.01)
RO (Sgcr=.10)
RG (Sgcr=.10)
RO (Sgcr=.20)
RG (Sgcr=.20)

Fig. 16



2000
1500
1000
500
0
20000
15000
10000
5000
0
10
100
1000
10000
100000
Oil Plateau Production Rate, STB/D
Gas Plateau Production Rate, Mscf/D
Initial Producing GOR, Sm3/Sm3
RO(MB)
RG(MB)

Fig. 17

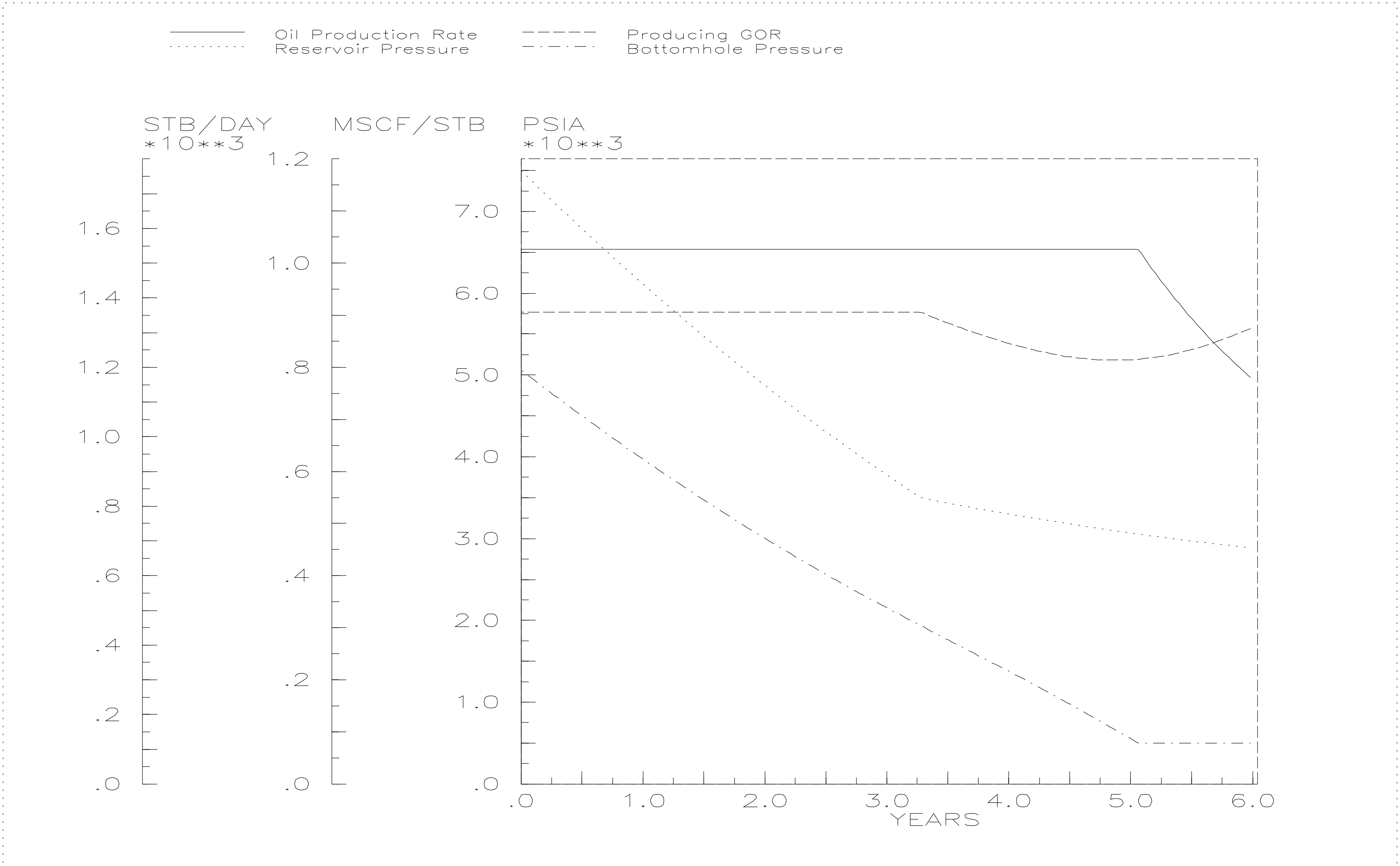


Fig.18 Plateau Production Rate, Material Balance Model (RSi=906 scf/STB

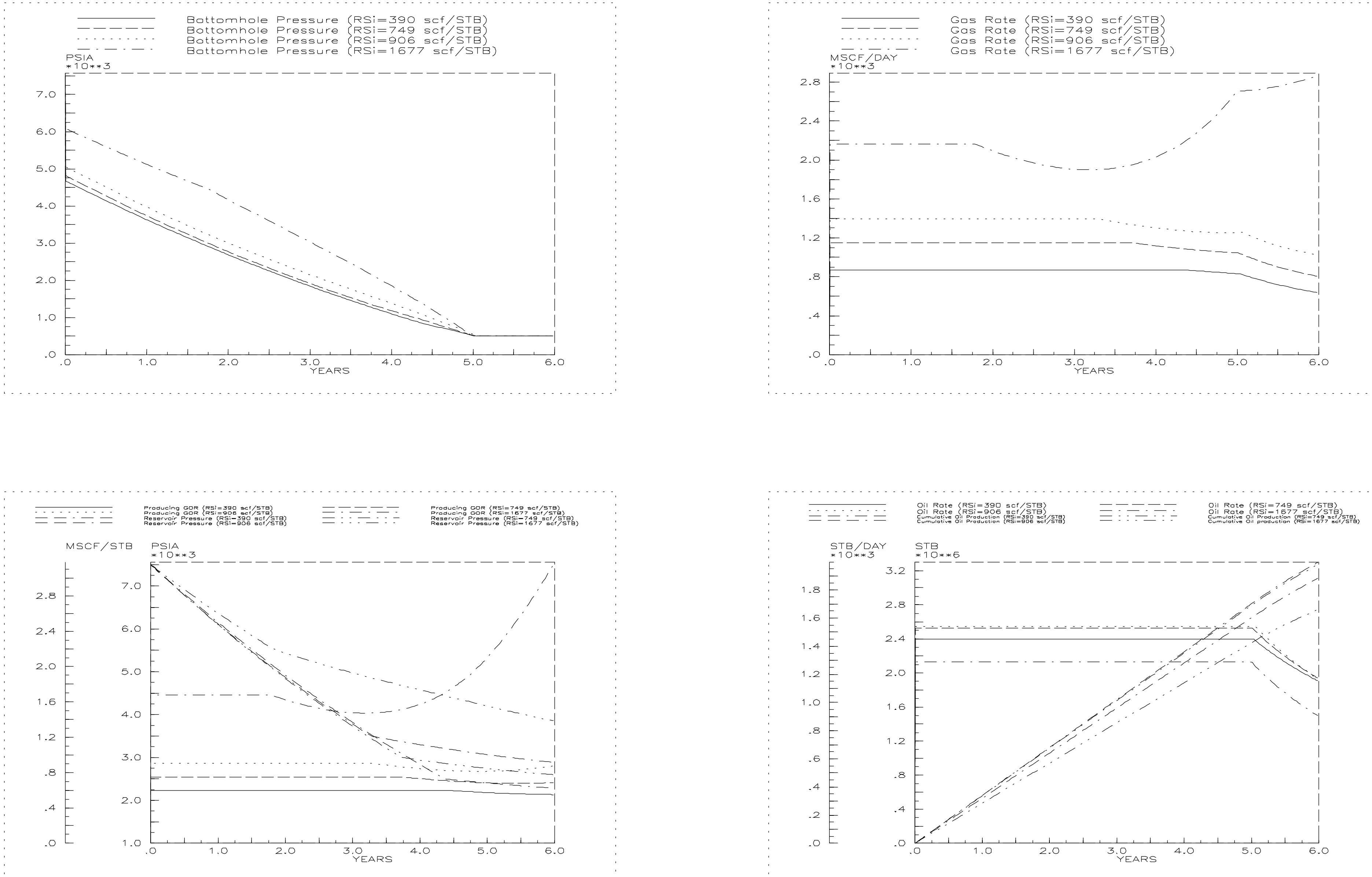
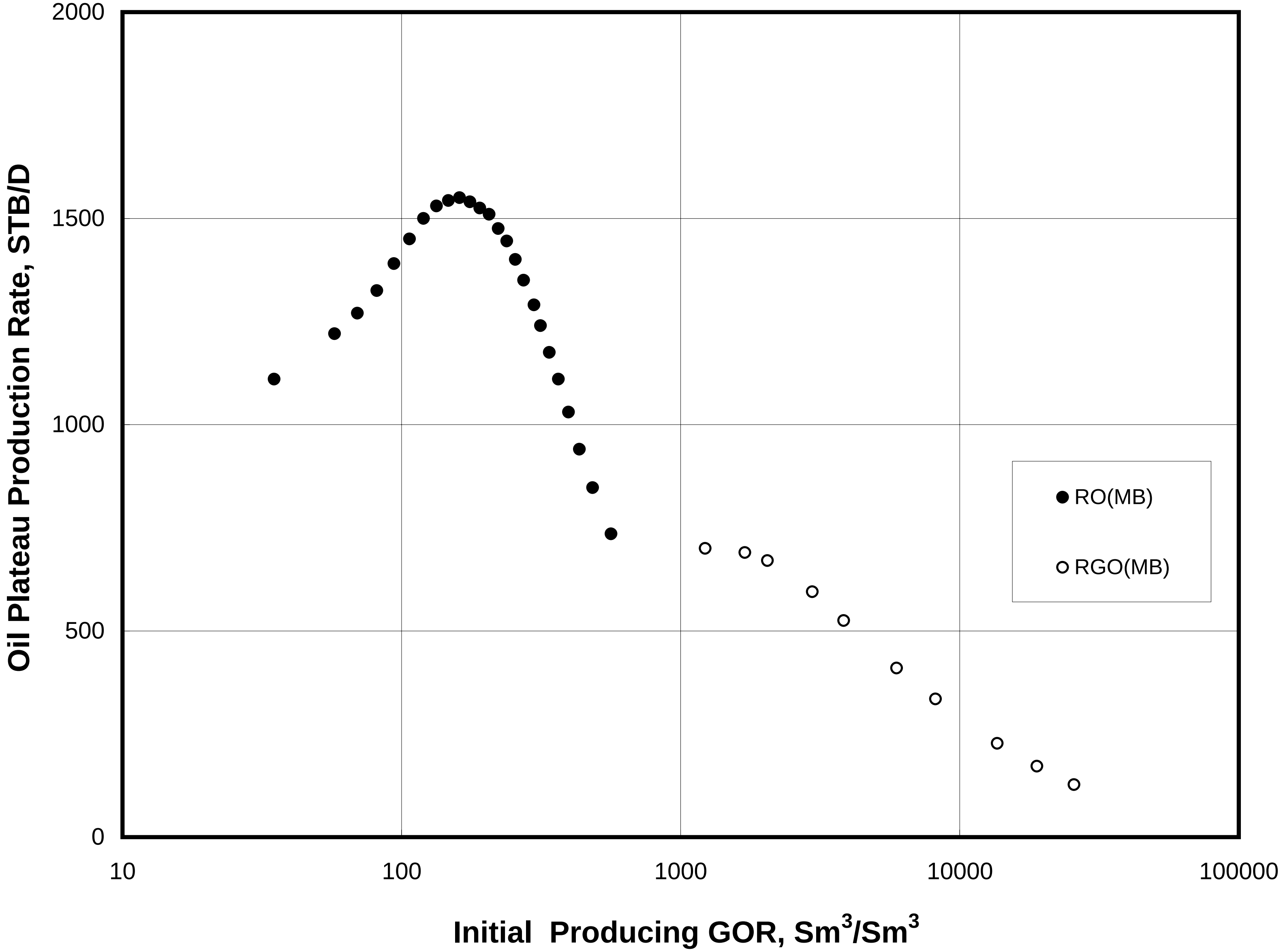
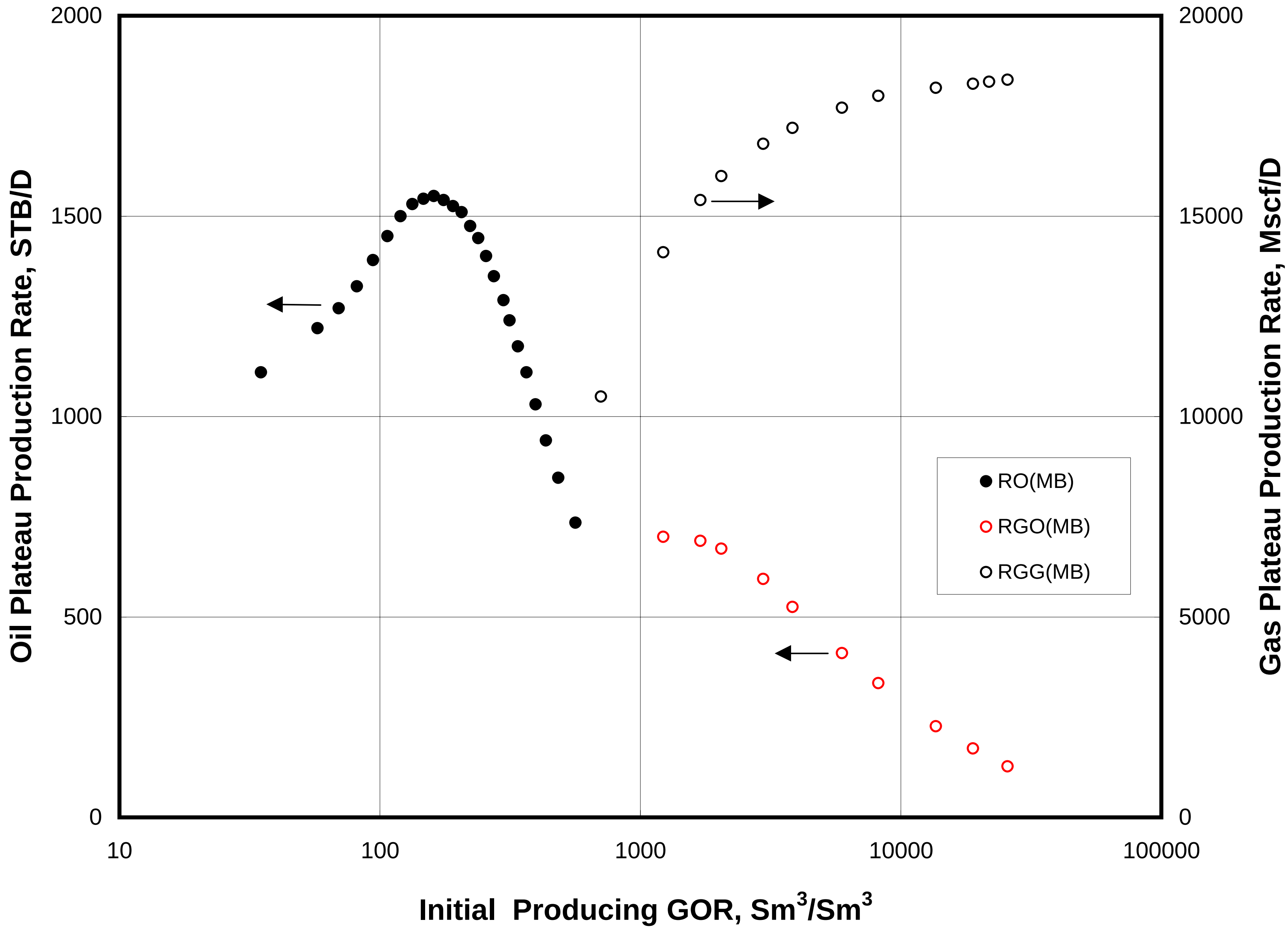


Fig.19 Plateau Production Rate, Material Balance Model



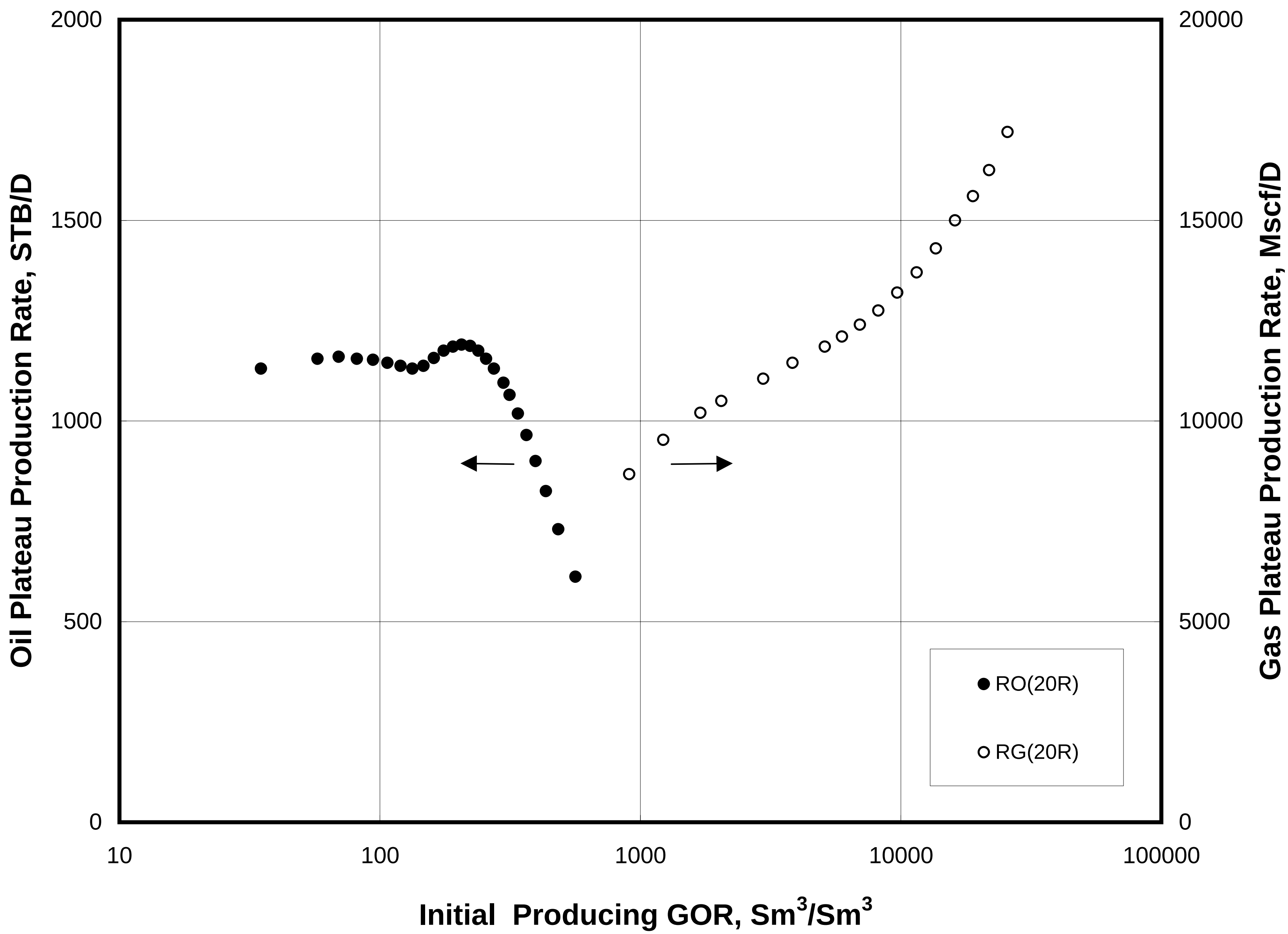
2000
1500
1000
500
0
10
100
1000
10000
100000
Oil Plateau Production Rate, STB/D
Initial Producing GOR, Sm3/Sm3
RO(MB)
RGO(MB)

Fig. 20



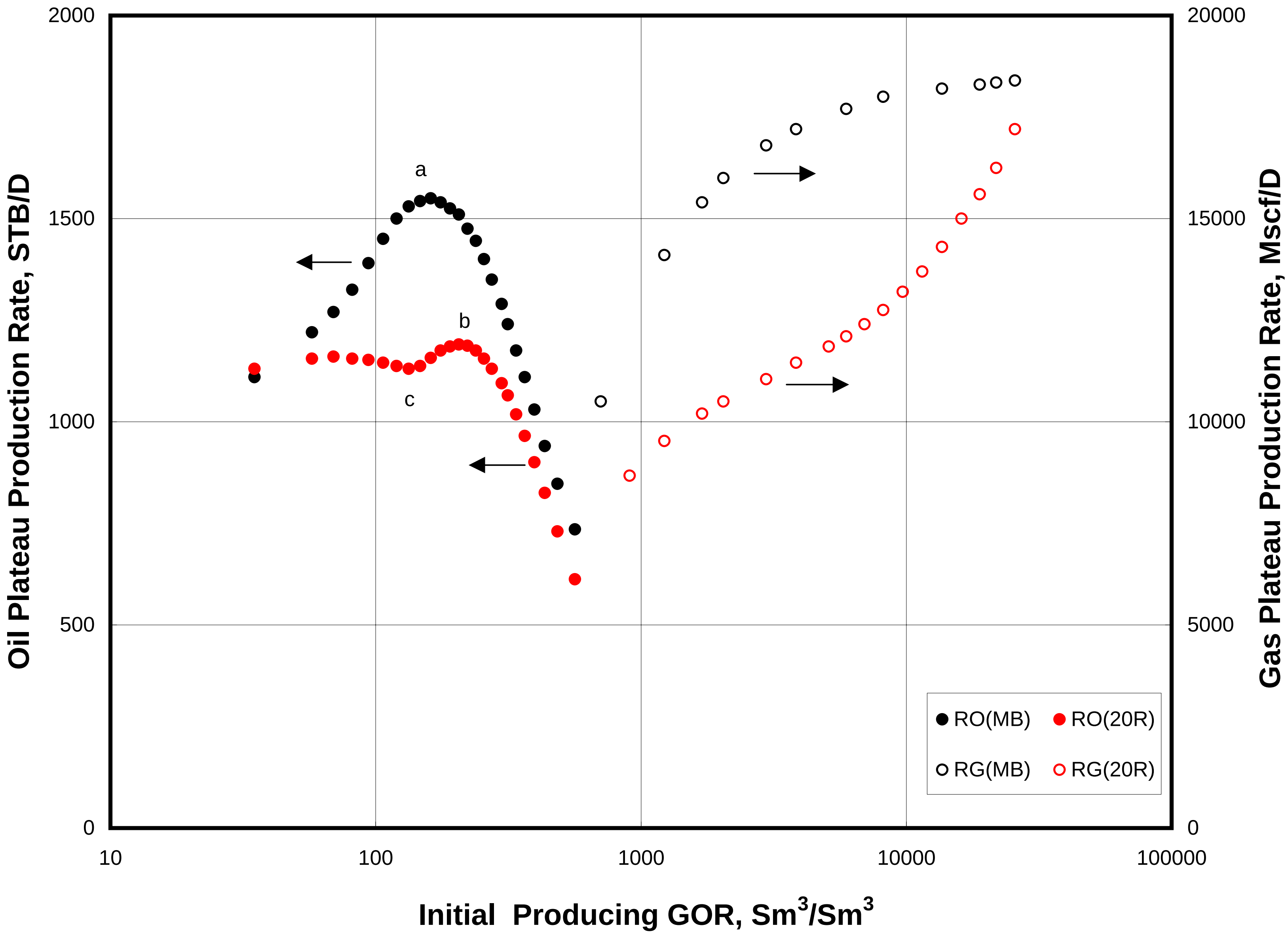
2000
1500
1000
500
0
20000
15000
10000
5000
0
10
100
1000
10000
100000
Oil Plateau Production Rate, STB/D
Gas Plateau Production Rate, Mscf/D
Initial Producing GOR, Sm3/Sm3
RO(MB)
RGO(MB)
RGG(MB)

Fig. 21



2000
1500
1000
500
0
20000
15000
10000
5000
0
10
100
1000
10000
100000
Oil Plateau Production Rate, STB/D
Gas Plateau Production Rate, Mscf/D
Initial Producing GOR, Sm3/Sm3
RO(20R)
RG(20R)

Fig. 22



Oil Plateau Production Rate, STB/D
Gas Plateau Production Rate, Mscf/D
Initial Producing GOR, Sm^3/Sm^3
2000
1500
1000
500
0
20000
15000
10000
5000
0
10
100
1000
10000
100000
a
b
c
RO(MB)
RO(20R)
RG(MB)
RG(20R)

Fig. 23

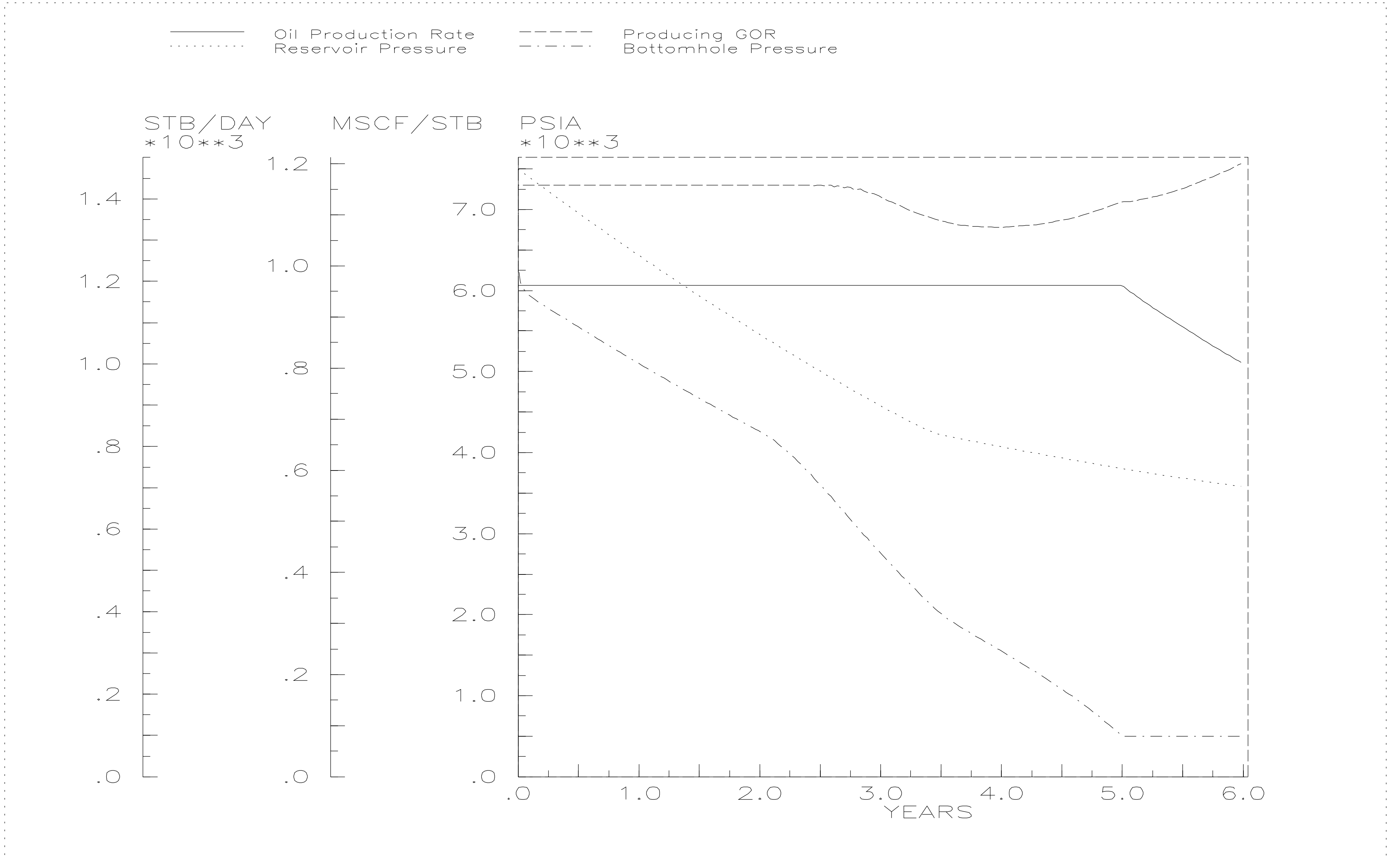


Fig.24 Plateau Production Rate, Radial Model (RSi=1158 scf/STB)

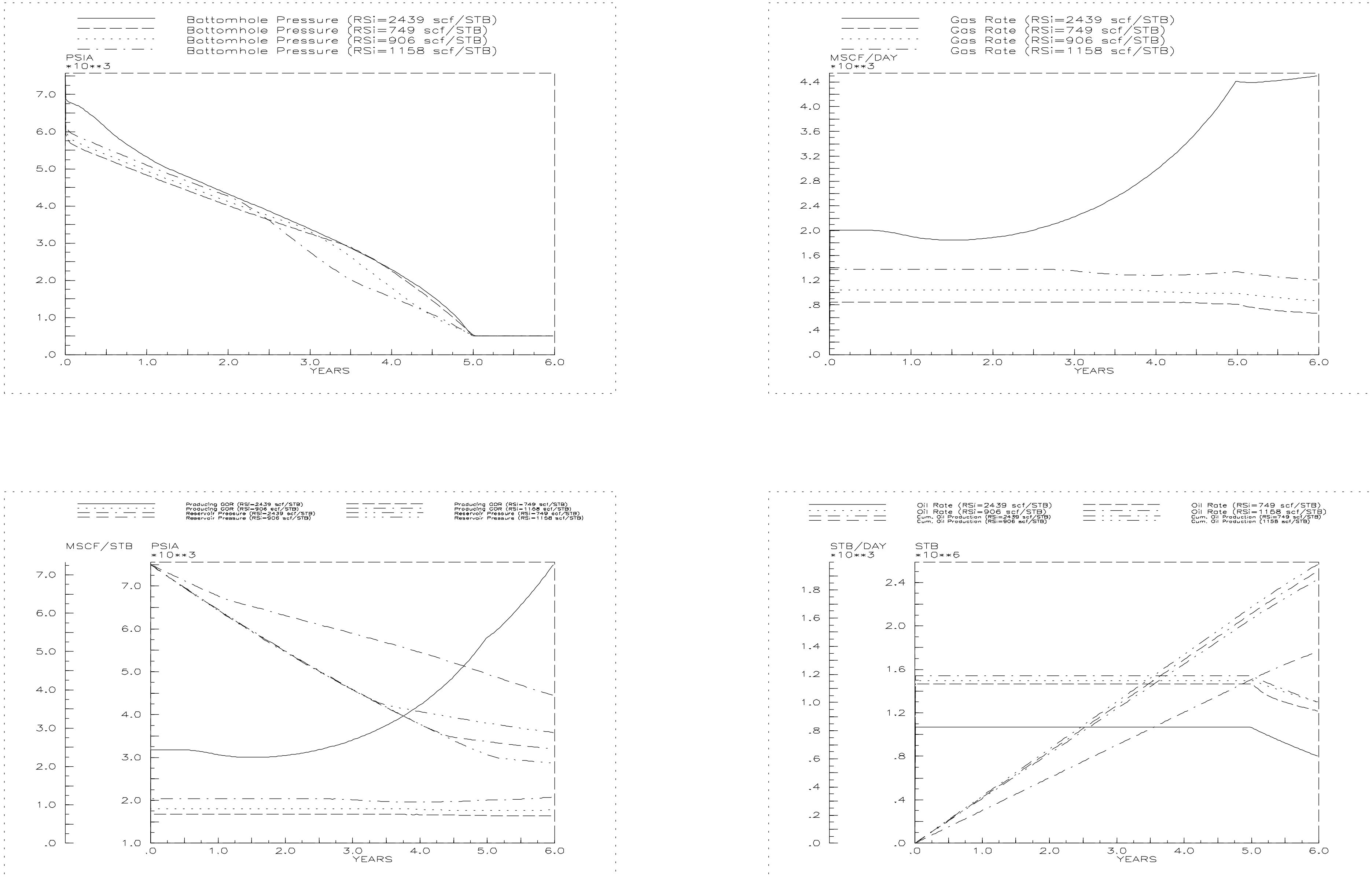


Fig. 25 Plateau Production Rate, Radial Model

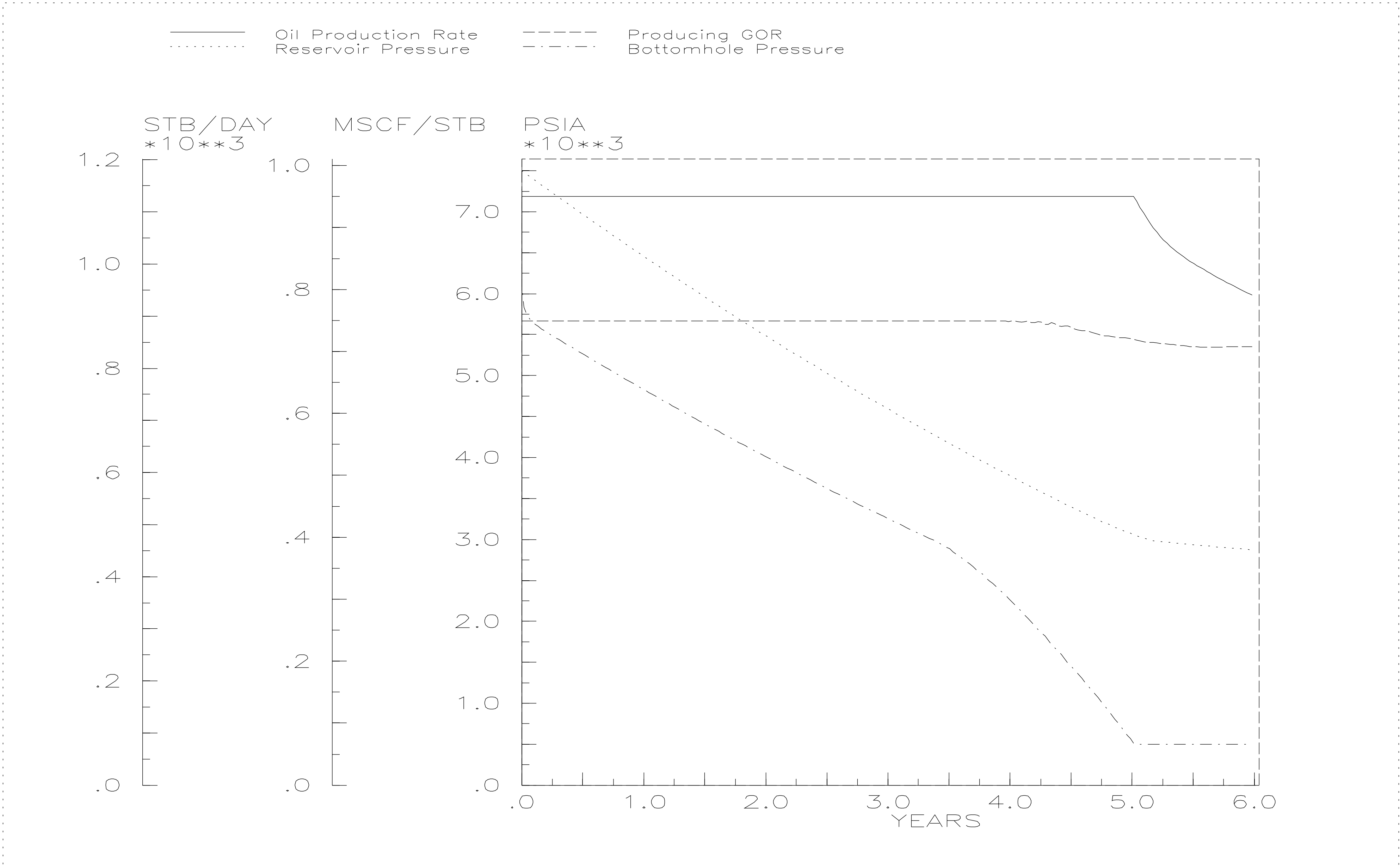


Fig.26 Plateau Production Rate, Radial Model (RSi=749 scf/STB)

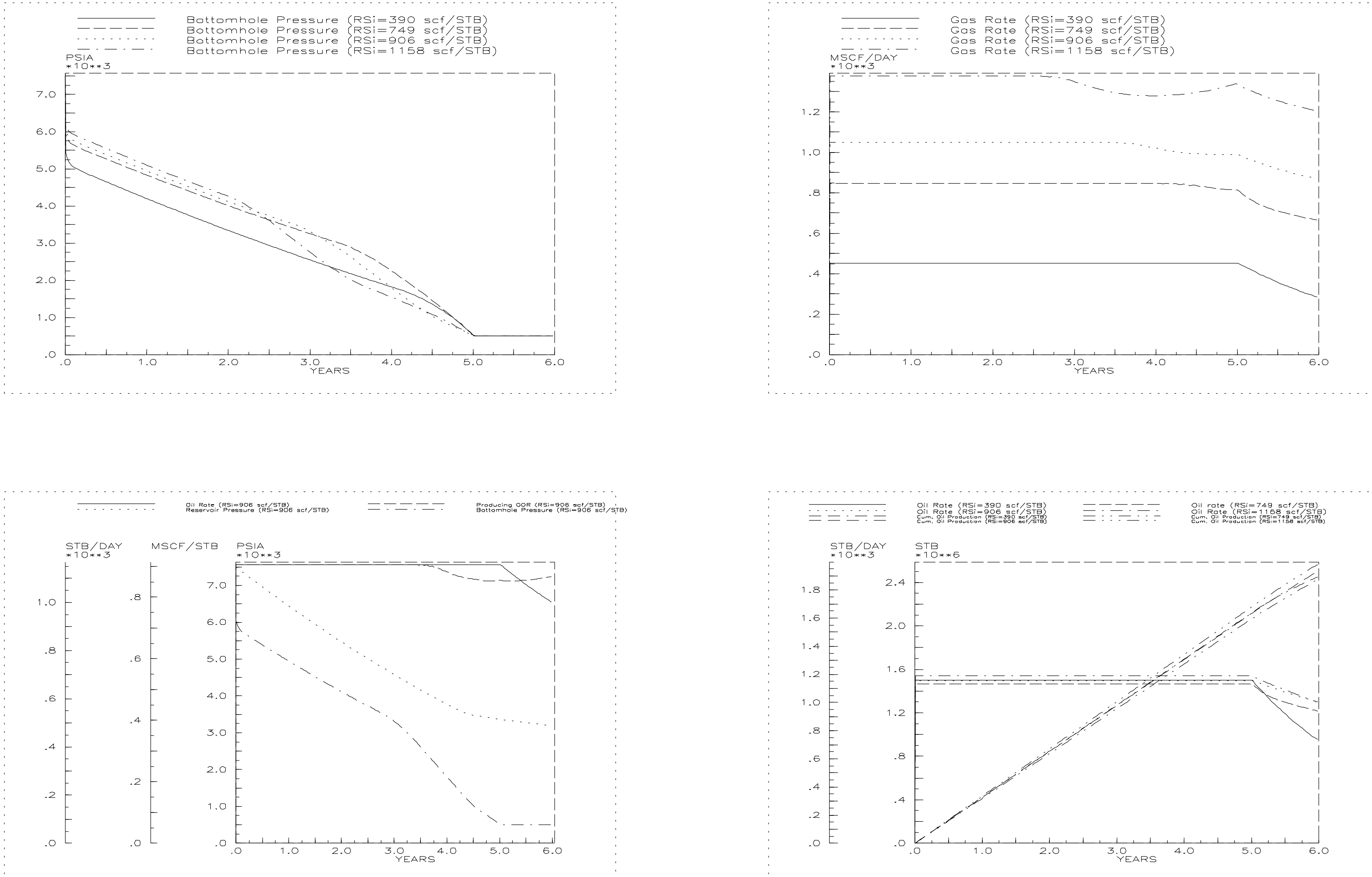


Fig.27 Plateau Production Rate, Radial Model

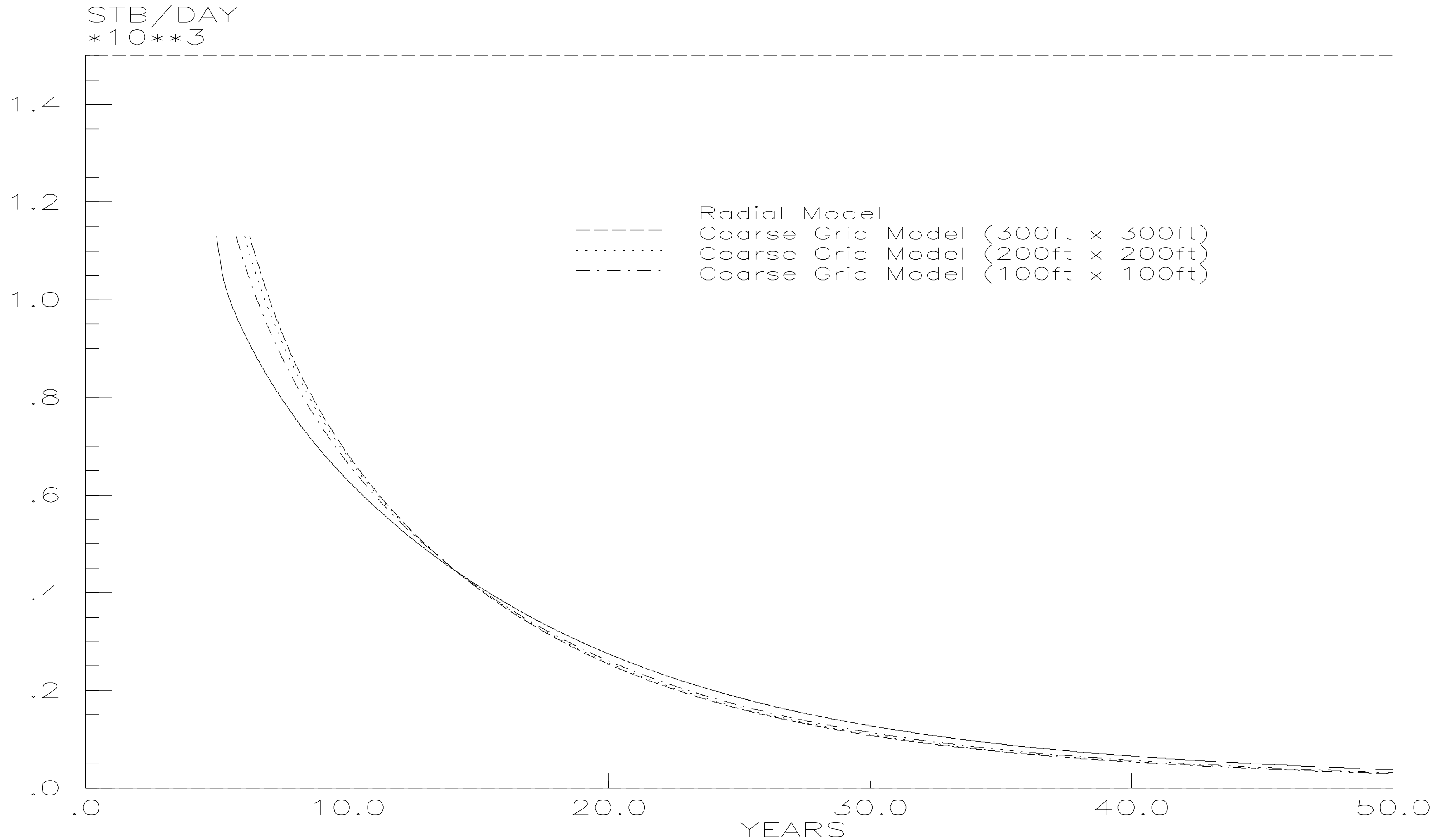


Fig.28 Plateau Production Period in Different Models (RSi=749 scf/STB)

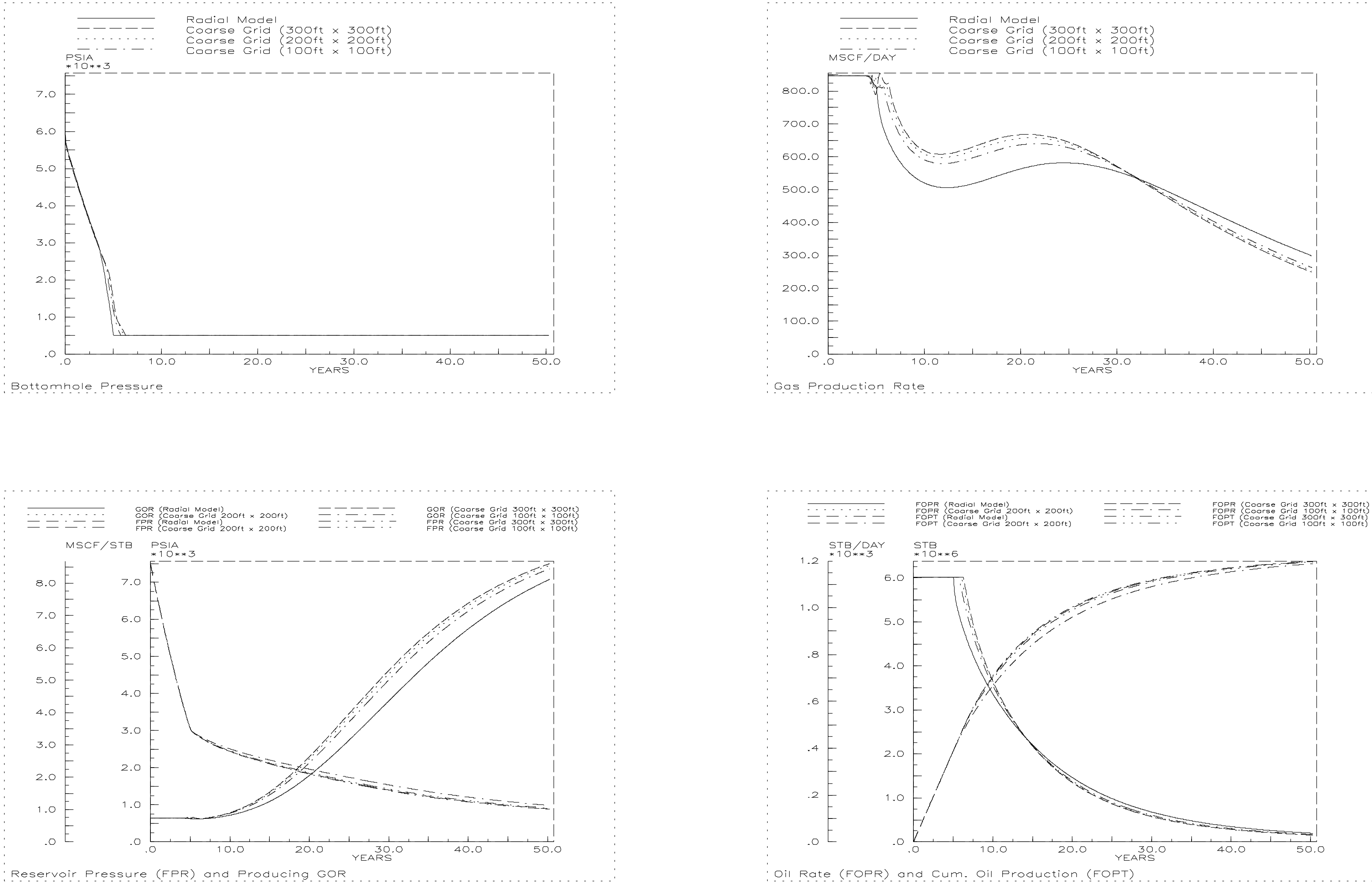


Fig.29 Plateau Producition Period, Different Models (RSi=749 scf/STB)

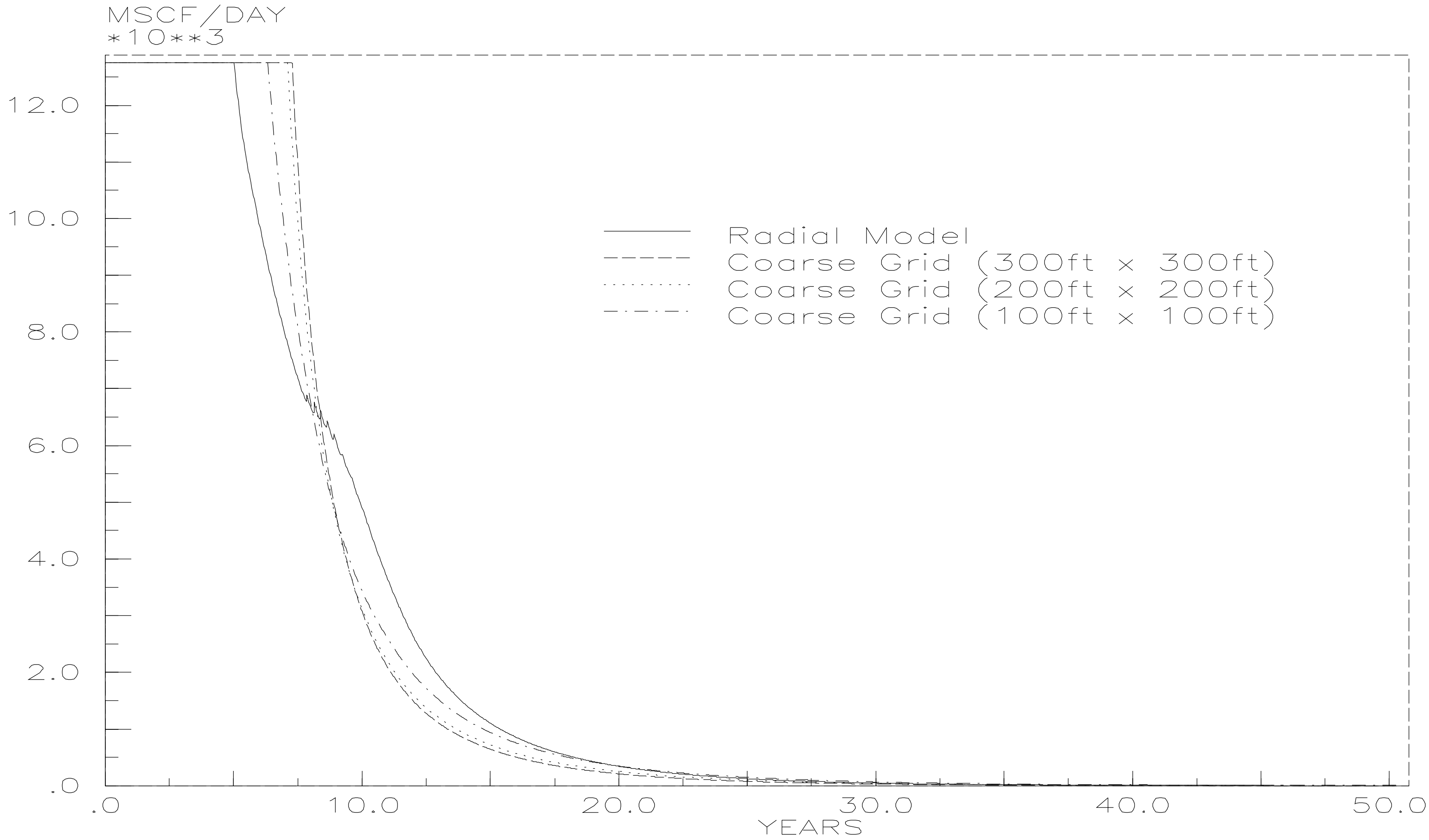


Fig.30 Plateau Production Period, Different Models(RVi=21.724 STB/MMscf

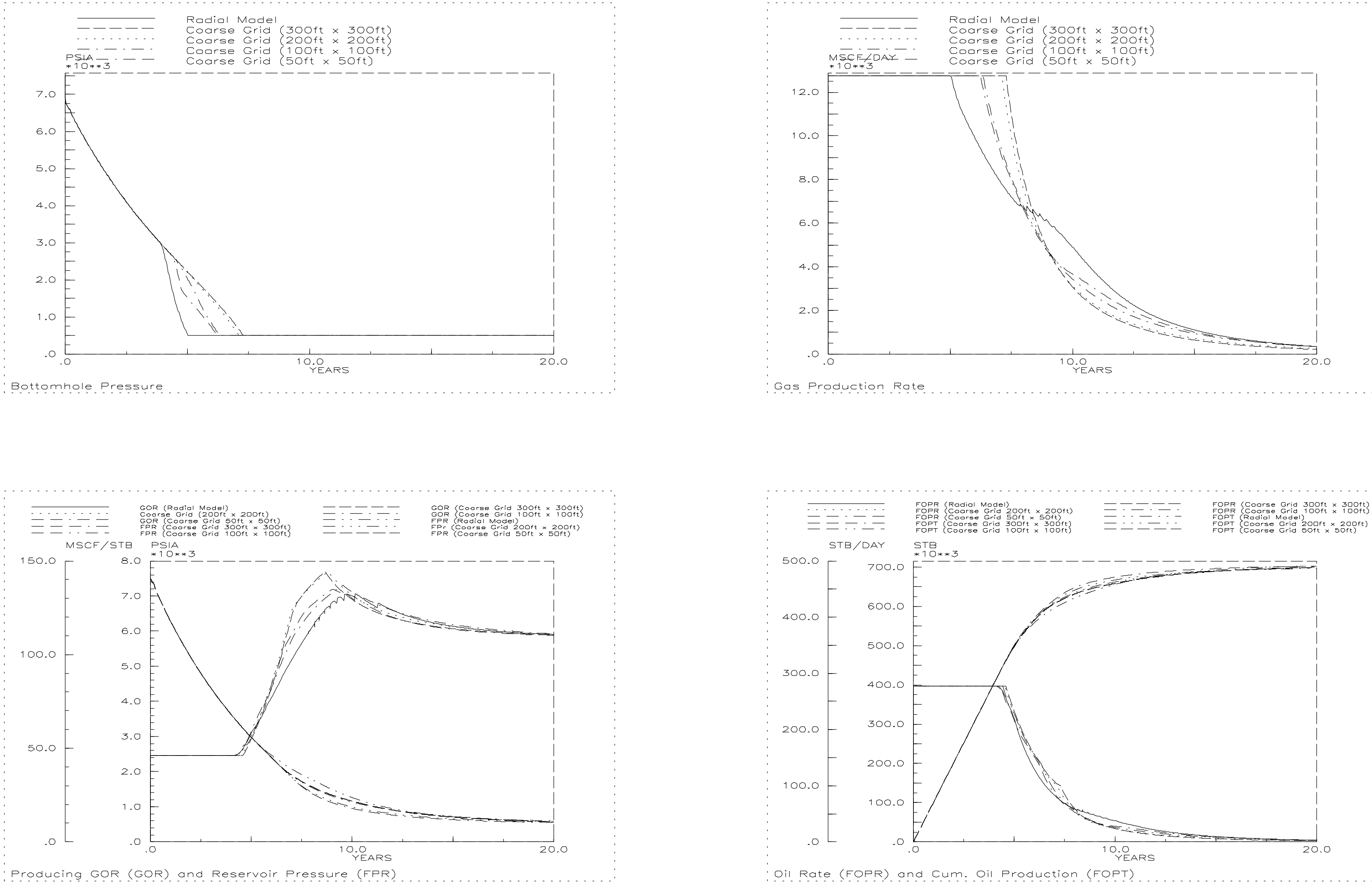


Fig.31 Production Performance (RVi=21.724 STB/MMscf)

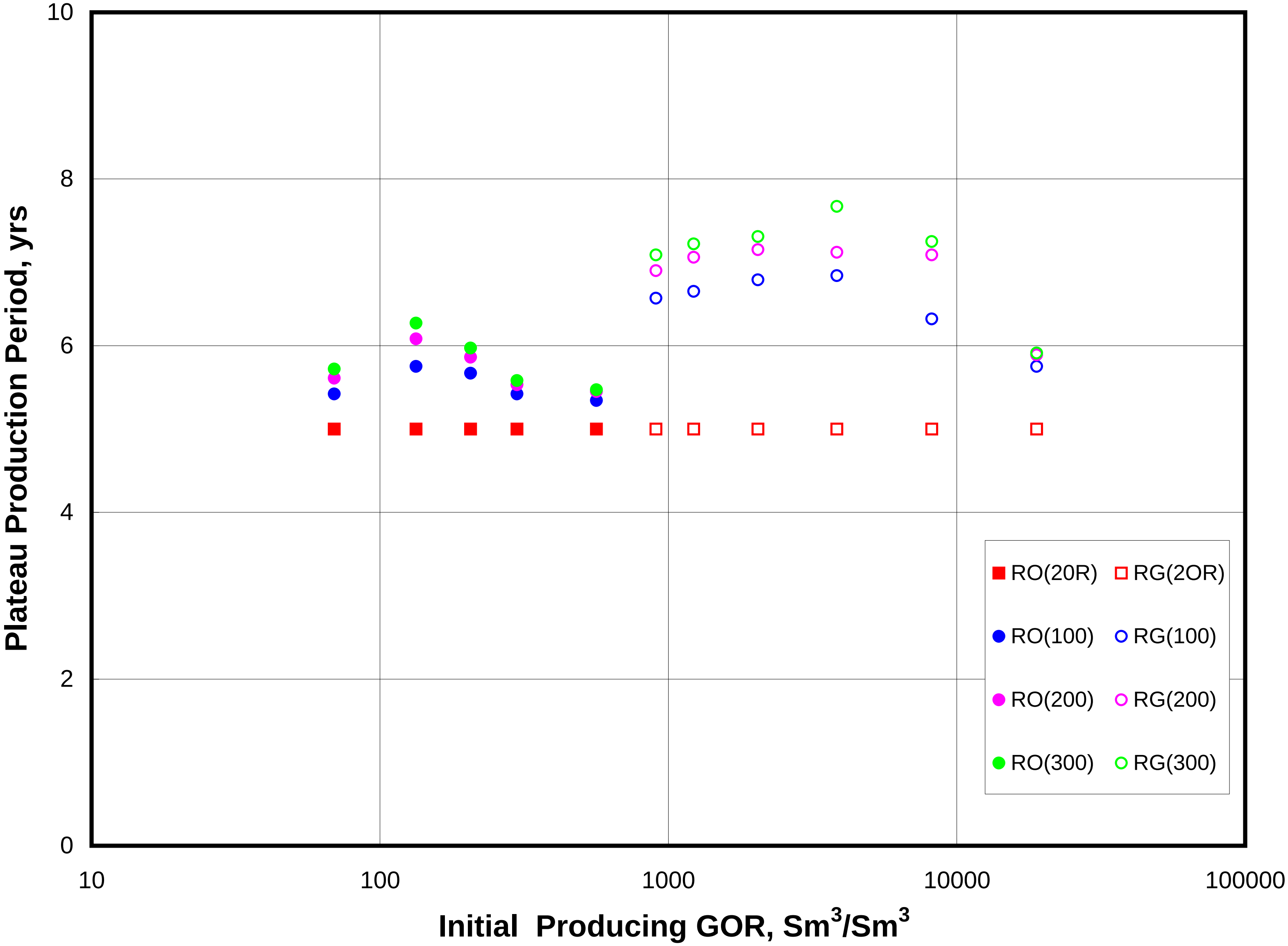

10
8
6
4
2
0
10
100
1000
10000
100000
Plateau Production Period, yrs
Initial Producing GOR, Sm3/Sm3
RO(20R)
RG(2OR)
RO(100)
RG(100)
RO(200)
RG(200)
RO(300)
RG(300)

Fig. 32

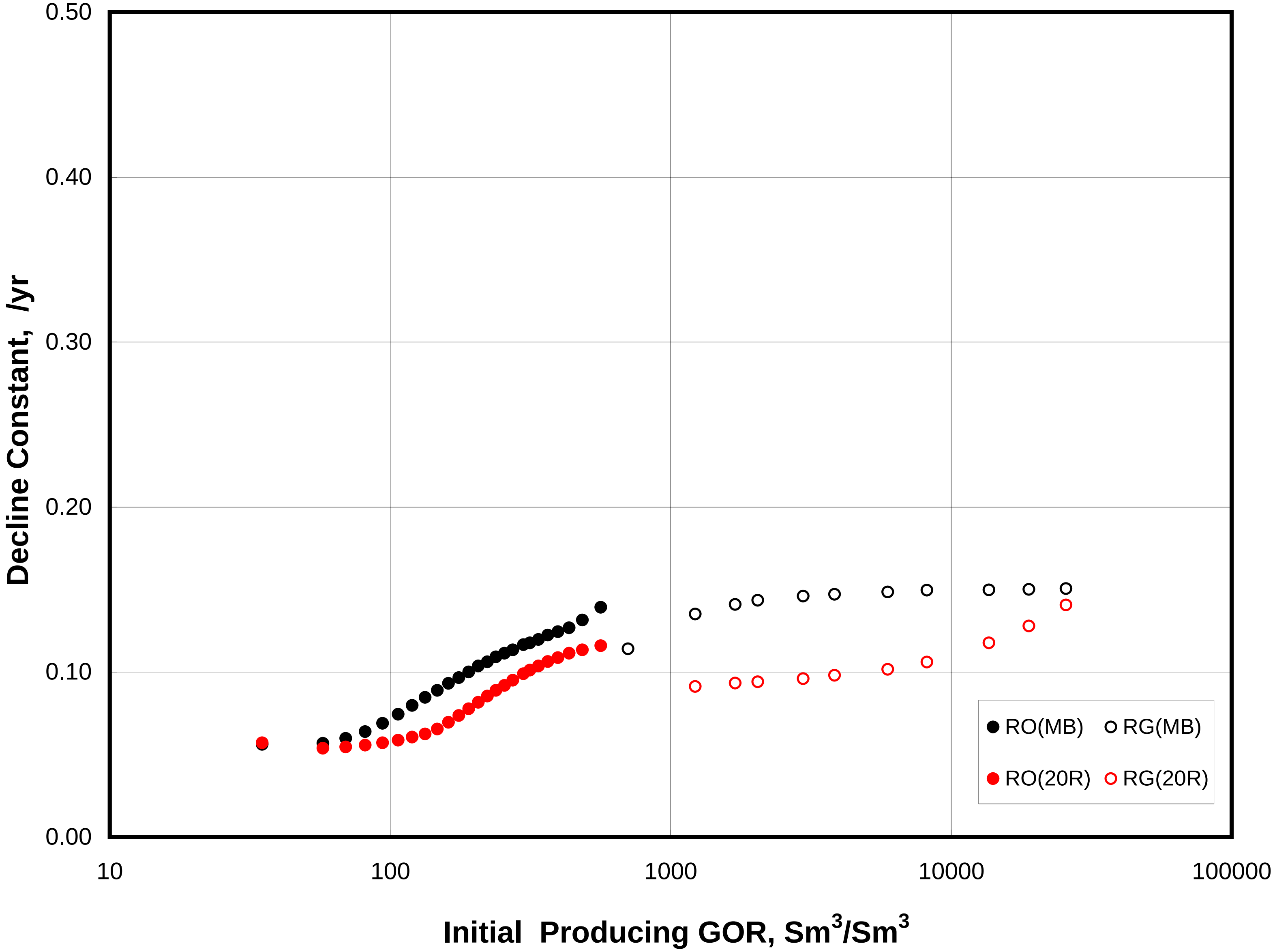

0.50
0.40
0.30
0.20
0.10
0.00
10
100
1000
10000
100000
Decline Constant, /yr
Initial Producing GOR, Sm3/Sm3
RO(MB)
RG(MB)
RO(20R)
RG(20R)

Fig. 33