THE HYDROCARBON PRODUCTION IMPROVING TECHNOLOGY

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SUMMARY

An advanced Technology has been developed and implemented for oil and gas production enhancement as well as to increase the total recovery. It is based on reservoir rock medium properties and physical processes within, and their control. The Technology employs seismic vibrations generated at the surface all across the oil field, which leads to higher stressed state level of the medium, and, respectively, to higher reservoir pressure and the production rate, and recovery therefore increases.

INTRODUCTION

The principally new features of the Technology are as follows:

1. This methodology of the oil field study has the purpose of identifying and using of a medium parameter that has not previously been taken for consideration – the stressed state.

2. This methodology of oil field study has the purpose of identifying and using another medium parameter that also has not been considered before - the distribution of local internal geological segments, which are sensitive and insensitive to external influences.

3. Influences (impacts) are administered from the surface with the seismic vibrators.

4. The vibrations produced from the surface make it feasible to intensify the oil and gas production and increase total recovery without any other production stimulation operations (1).

The basis of the Technology is the discovery of a previously unknown regulator of the behavior of weak high frequency seismic signals.

The application of the Technology includes the following steps:

1. Geological, geophysical and technological data consideration, and preliminary background observation, including the following:

    - conducting various seismic studies of the entire field;
    - conducting a gravity and topographical survey of the oil field;
    - conducting stratum pressure measurements;
    - studying of the production rates of all of the oil field wells.

2. Development of the oil field stressed state mathematical and computer model.
3. Development of the mathematical and computer model of the effects to be introduced.
4. Administration of the vibration effect program.

Depending on the reservoir rock medium and fluid properties, as well as the geological and geophysical peculiarities of the formation structures, improved production will continue for 6 to 15 months. After this period, the whole stimulation procedure must be repeated. As practical research has shown, a 3 – 6 month cycle is the most beneficial and economically profitable. This will allow the maintenance of high stratum pressure and the additional oil production.

The Technology is very environmentally friendly. It is believed that the effect of the medium stressed state and reservoir pressure increase prevents the destruction of the geological reservoir. The Technology does not require any water and chemical injections or other stimulation operations, and, thus, decreases the pollution. It affects the reservoir fluid, and due to the alteration of its physical properties, the percentage of oil within the extractable liquid increases significantly. In other words, the Technology prevents water encroachment from the external sources, and, thus, decreases the watercut.

The vibrational impacts aimed at the certain points in the oil field cause the redistribution of the stress field within the reservoir rock along with the production stratum. This causes its partial restructuring, an

intensive seismic emission, and, as a result, the emergence of new drainage areas. In particular, the tension of the reservoir rocks occurs within the pay zone and opens the compressed pores.

The effect of vibrational forces decreases the oil viscosity and increases the filtration processes dramatically. This impacts the finely dispersed reservoir zones of low permeability, and releases the great volumes of immobile oil.

I. THE RESULTS OF THE TECHOLOGY IMPLEMENTATION IN THE AZERBAIJAN OIL FIELDS

Since August, 1995, the Technology was employed on the Kala and the Old Kala oil fields, which are located in the Absheron peninsula (Azerbaijan), operated by the Azizbekovneft OGPD (Oil and Gas Production Department). These small oil fields have been exploited for more than sixty years. The water cut varies between 92 – 93%, and oil content is approximately 8% in the liquid produced, which at 2,000 – 2,100 tons per month (15,000 – 15,500 bbl) is considered extremely low.

During August through December 1995, the geological and geophysical parameters were gathered, and the stressed state and vibrational influence models were developed.

The vibrational impacts were started in December, 1995. Initially the reservoir pressure increased by 3 – 10% and the production rate from each oil-bearing horizon, increased by (depending on horizon) from 10 to 50%.

In January, 1996, based on the actual data analysis, some corrections were made in the vibrators' locations and their modes. As a result, in February a considerable increase in the reservoir pressure and oil production rate was noted in all nineteen oil-bearing horizons.

From March through August, 1996 the seismic observations, the reservoir pressure measurements and the evaluation of medium stressed state degree were continued. The quantity of the additional oil production was estimated based on the daily oil and water production rate. All measurements were done by OGPD personnel. The additional oil production was not only a result of the above mentioned effects but also by putting into production the temporarily shut-in wells, which started to produce after the described operations.

In comparison with the production rates in November, 1995, the data indicated a significant increase in the output during the nine months as a result of the vibrational influences. The data showed monthly summary oil production increase as follows:

December – 19.7%, January – 22.5, February – 15.7%, March – 31.5%, April – 18.7%, May – 23.7%, June – 13.1%, July – 19.2%, August –17.4%.

Figure 1 shows oil production changes of the Kala and Old Kala oil fields for the January, 1993 – August, 1996 period. It was established, that oil production of the both oil fields increased sharply since December, 1995.

Before the works started, the linear approximation of the parameters was:
$Y = -31.239X + 3613.4$. After the works began it became:
$Y = 13.933X + 2311.5$.

Confirmation of the substantial changes of the medium stressed state was also noted by the measurements of the other geophysical parameters.

The repeated first class leveling covering the entire oil field territory of several dozens of square kilometers reflected the vertical movements of surface, which level rose by 25-30 mm in average.

Figure 2 shows the map of the earth surface changes across the territory of the Kala and Old Kala oil fields in response to exposure to the vibrational impacts.

Figure 3 shows the diagram of the oil and water production alteration following by the exposure to the vibrational influences during the December, 1995 – February, 1996 period for the Kala and Old Kala oil fields.

Despite the low production rates of the Kala and Old Kala oil fields, the additionally produced oil during the period of December, 1995 – August, 1996, exceeded expenses by many times. The achievement of equivalent production rate increases with the traditional methods of the well stimulation would require additional drilling, fracturing, acidizing, various flooding programs and others. The results from these traditional methods are not predictable, and the payback period may take several years (2,3).

II. THE RESULTS OF THE TECHNOLOGY IMPLEMANTATION IN THE TATARSTAN OIL FIELDS

1. IMPLEMENTATION OF THE TECHNOLOGY

Beginning in September, 1996, the Technology was employed in the
closely located Komarovskoye and Pervomayskoye (blocks 3 and 4) oil fields, and since July, 1997, in the relatively distant Bondyujesk oil field, all operated by the Prikamneft OGPD.

These oil fields have been in production for more than 25 years and are characterized by a high water cut. Average monthly oil production for the above mentioned oil fields was 2,500 tons (18,500 bbl), 15,000 – 18,000 tons (111,000 – 133,000 bbl) and 27,000 – 30,000 tons (200,000 – 222,000 bbl), respectively.

In accordance with the program, all necessary preliminary background evaluations were conducted prior to the oil fields' exposure to the vibrational impacts.

On the basis of the achieved results and along with the additional information, the stressed state model for the oil fields as well as the vibrational impact model were established.

Vibrational impacts in the Komarovskoye and Pervomayskoye oil fields began on November 26 and proceeded continuously until December 28, 1996 with the two CB-10/180 vibrational units. The increase of the reservoir pressure and oil production rate was noted in December. In January, 1997, the well tests showed that the reservoir pressure measured in 15 piezometric wells increased after the works started by 0.3-1.1 MPa in comparison with November, 1996. The oil production increase in December and subsequent months was 20% or more.

Figure 4 shows the reservoir pressure variation for the November, 1996 – January, 1997 period.
In February, 1997, on the basis of the obtained data and analysis, the adjustments to the vibrators' location and their operating modes were done.

In March, 1997, the vibrational treatments were repeated. This led to an even greater increase in the reservoir pressure and the oil production rate for practically all of the wells. During the following months the monthly production of oil exceeded that prior to the vibrational impacts production by 20-25%.

Confirmation of the considerable changes in the medium state was also noted by the measurements of other geophysical parameters. The topographic and gravimetric observations made at 25 locations covering the territory of over one hundred kilometers displayed that the earth surface level rose by 30-110 mm and the gravitational field level increased by 60-200 microgal compared to original conditions

Figure 5 shows the difference of the gravitational field level before and after the vibrational impacts in milligals.

Figure 6 shows the difference in the earth surface level before and after the vibrational treatments.

The important element of the Technology is the identification of tension points sensitive to the vibrational impact condition. For this purpose the seismic survey of the region and the tests of the vibrational impacts were conducted.

Figure 7 shows the distribution of the seismic noises within the territory after the Technology implementation.

A comparison of the Figure 7 and 8 makes it possible to select the correct points for applying of the vibrational impacts.
The measurement of the increased production of oil was made based upon of the sample analysis and the volume of liquid was determined using the force-out curves taken for this region.

Subsequently, in the territories of the above mentioned oil fields, the continuous seismic observations and reservoir pressure measurements, as well as the gravitational and topographic surveys, were conducted.

The required corrections for the medium and vibrational impact models were made. According to the obtained data, the vibrational influences were repeated every three to four months.

2. ANALYSIS OF THE RESERVOIR PRESSURE VARIATIONS AND THE WATERCUT

The figures below show the changes in the reservoir pressure and watercut, providing

strong evidence of the high ecological and economical effectiveness of the Technology.

The results prove convincingly that the Technology allows maintenance of the natural conditions of the oil field for a long period of time. It prolongs the production life and maximizes the total oil recovery.

The Technology was tested during the past ten years in seven oil fields. The extensive statistical data shows that the increase in oil production was 20-25% on average, and that the payback period is two to four months. Compared to any other methods, where the payback period is measured in years, this is an exceptionally high result.

Additionally, as it is shown by the results, the Technology can be used within all geological structures.

While the Kala and old Kala oil fields have the classic anticline dome-shaped structures with a pitch of side angles of 40-50º, the Komarovskoye, as well as Pervomayskoye and Bondyujskoye oil fields, are situated in zones of the platform type with the pitch angles of 1-7º. The reservoir pressure varied from 7.0-8.0 MPa to 22.0-23.0 MPa, and watercut from 40% to 90%, and more.

The Technology also can be employed in reservoirs having a very wide range of depths, thickness and watercut percentages.

However, it seems undesirable to apply the Technology in the reservoirs of the predicted low total recovery (about 10%). Such kinds of reservoirs consist of high plasticity rocks, and, as a rule, are characterized by the diatomite formations. We do not have experimental data for these types of reservoirs.

Figures 8-10 show the changes in the reservoir pressures for the entire working period in the Komarovskoye, Pervomayskoye and Bondyujskoye oil fields. The dotted lines indicate the periods when the monthly-based measurements were not conducted. The figures reflect the moments of the reservoir pressure corresponding to the beginning of the each cycle of the vibrational influences applied in each field. According to these graphs, the duration of the treatment period, when the reservoir pressure remains at the higher level, is three to six months on average.

Figures 11-12 display the variations in the watercut for the high-producing wells. The numbers of the wells are as follows:

The third block of the Pervomayskoye oil field: 139, 517, 525, 721, 722, 1476.

The fourth block of the Pervomayskoye oil field: 512, 640, 645, 652, 756,

766, 772, 773, 1367, 1368, 1372, 1373, 1377, 1385.

The central block of the Bondyujskoye oil field: 62, 66, 210, 234, 250, 253, 264, 267, 282, 283, 288, 298, 323, 324, 351, 352, 368, 1134.

The southern block of the Bondyujskoye oil field: 60, 228, 241, 262, 263, 274, 275, 277, 280, 281, 290, 292, 293, 305, 306, 311, 313, 314, 315, 319, 320, 322, 356, 367, 380, 383, 391, 392, 394, 404.

These results strongly support the high efficiency of the Technology. For this period, the

production samples showed the considerable reduction in the rise of the watercut (17 wells). A decrease in the watercut was indicated in the 50 wells. All the data was compared with the prior sample analysis of each field.

As it was mentioned before, the Technology affects the reservoir fluid, and due to the changing of its physical properties, the percentage of oil within the extractable liquid increases significantly. In other words, the Technology prevents water encroachment from the external sources, and thus, decreases the watercut.

The Technology was applied in more than seven oil fields. During the past four years it was employed in five oil fields located in Azerbaijan and Tatarstan. These oil fields each have different watercut performance varying from 10%, 20% and 50% up to 90% and even more. But for each field the results stay the same as it is shown in Figures 11-12. Disregarding the main results, such as the oil production enhancement, this particular data may be of interest for the petroleum professionals.

The described practical material proves conclusively, that the Technology can be applied to all geological structures with a very wide range of depths, reservoir pressures and watercut percentages.

3. STUDYING OF THE TECHNOLOGY EFFECTIVENESS BETWEEN DECEMBER, 1996 AND JULY, 1998

The extensive statistical and practical data based on tens of thousands measurements conducted for over 120 months in several hundreds wells in five different parts of the oil fields, were gathered and computed. This includes:

- oil production data for nine years before the works started (January, 1988 – November, 1996), and for the period of work (December, 1996 – July, 1998)

- the OGPD data pertaining to the water flooding program for the three years before the work started, and then

- analyzing the data with the linear and polynomial approximations

- comparative analysis of the gradient alterations in the oil production and watercut.

The Figures and Table, illustrating the additional oil production for the Komarovskoye, Pervomayskoye and Bondyujskoye oil fields, are enclosed. All the data were taken from the OGPD production reports and files and the current data was based on the measurements of the oil and water production volumes and their respective percentages.

Figures 13-15 indicate the oil production changes in the Komarovskoye, Pervomayskoye and Bondyujskoye oil fields for the period of January, 1988 – July, 1998.

As it follows from the data, during the entire program period, the linear approximation indicates the distinguished changes and growth of the oil production in comparison with the preliminary nine years.

The graphs, shown in Figure 14, show that the vibrational signals initiated in the Pervomayskoye oil field started effecting the Bondyujskoye oil field 1.5-2 months later. The Bondyujskoye field is located 10 to 25 km away. These signals affected very strongly the oil production of the Bondyujskoye oil field. Subsequently, the direct vibrational impacts initiated in July, 1997 in the Bondyujskoye oil field, resulted in a yet sharper production increase.

Thus, while initial vibrational influences induced considerable oil production increase in both the Komarovskoye and Pervomayskoye oil fields, it also benefited the Bondyujskoye oil field.

The linear approximations (Figures 13-15) make it possible to obtain numerical values characterizing the tendencies of the oil production change before and during the works.

Figure 13 – the Pervomayskoye-3 oil field:

Before the work started, the linear approximation of the parameters was:

$Y = -32.236X + 8899.0.$

After the works began it became:

$Y = 28.416X + 7219.1.$

The Pervomayskoye-4 oil field:

Before the work started, the linear approximation of the parameters was:

$Y = -83.61X + 14677.0.$

After the works began it became:

$Y = 144.13X + 6293.1.$

Figure 14 – the Bondyujskoye-centre oil field:

Before the work started, the linear approximation of the parameters was:

$Y = -94.778X + 17739.0.$

After the works began it became:

$Y = 242.42X + 9061.3.$

The Bondyujskoye-south oil field:

Before the work started, the linear approximation of the parameters was:

Y = -85.058X + 26509.0.

After the works began it became:

Y = 381.5X + 19202.0.

Figure 15 - the Pervomayskoye-3 and 4 oil field:

Before the work started, the linear approximation of the parameters was:

Y = -115.85X + 23576.0.

After the works began it became:

Y = 172.55X + 13512.0.

The Bondyujskoye-south and centre oil field:

Before the work started, the linear approximation of the parameters was:

Y = -179.84X + 44247.0.

After the works began it became:

Y = 645.8X + 27869.0.

The Pervomayskoye, Komarovskoye and Bondyujskoye oil fields:

Before the work started, the linear approximation of the parameters was:

Y = -320.53X + 71914.0.

After the works began it became:

Y = 798.97X + 43476.0.

Moreover, the water-flooding program decreased since the beginning of the work, which was confirmed by the measurements.

Figure 16 shows the correlation between the water flooding and the oil production alteration for the Pervomayskoye-4 and Bondyujskoye-south oil fields. The linear approximations for the water-flooding and oil production for the Pervomayskoye-4 oil field before the works respectively were:

Y = -787.67X + 148558.0

Y = -83.61X + 14677.0.

After the works began they became (in the same order):

Y = -542.5X + 87979.0

Y = 144.13X + 6293.1.

For the Bondyujskoye-south oil field the linear approximations for the water flooding and the oil production before the works respectively were:

Y = -230.43X + 214568.0

Y = -85.058X + 26509.0.

After the works began they became (in the same order):

Y = -1396.0X + 248699.0

Y = 381.5X + 19202.0.

In other words, the water-flooding program decreased considerably, and, at the same time, the oil production was enhanced dramatically.

This indicates an even better result. The oil production increase is accompanied by a significant decrease in the water flooding.

The OGPD data analysis indicates that during the nine years before the vibrational treatments started, the desirable result in the oil production enhancement was not achieved through the usage of any other of the

traditional methods of production stimulation. As it follows from the data, the best result, that had been accomplished, is the slowing down of the decline in oil production. It is possible to say that there are no methods used by OGPD or other companies, organizations or persons in previous years, which had comparable results with the vibrational impacts generated from the earth surface in accordance with the seismic wave method developed by us.

The data for the additional production during the period of December, 1996 – July, 1997 are in the Table. Due to the relatively low oil production rate of the Bondyujesk oil field in January, 1997, the data on additional production was compared with the average numbers for three previous months (November, 1996 – January, 1997).

The production data in the Table indicates that the additional oil produced for the work period was 210 thousand tons in total. This is more than 20% of the prior production rate for the respective oil fields.

Table. Additional oil production compared to November, 1996.

Date	Pervomayskoye + Komarovskoye fields, ton	Bondyujskoye field, ton	Total additional production, ton
1	2	3	4
XII/1996	3,316	-	3,316
I/1997	3,525	-	3,525
II/1997	2,288	2,371	4,659
III/1997	3,475	5,689	9,164
IV/1997	2,226	6,352	8,578
V/1997	6,355	6,597	12,952
VI/1997	3,814	2,071	5,885
VII/1997	3,052	6,444	9,496
VIII/1997	3,561	7,235	10,796
IX/1997	3,127	8,422	11,549
X/1997	2,014	7,318	9,332
XI/1997	2,511	13,416	15,927
XII/1997	3,026	9,385	12,411
I/1998	4,168	13,495	17,663
II/1998	4,655	16,273	20,928
III/1998	3,945	10,399	14,344
IV/1998	3,060	6,798	9,858
V/1998	3,912	4,110	8,022
VI/1998	4,696	3,418	8,114
VII/1998	4,450	8,041	12,491
Total	**71,176**	**137,834**	**209,010**

CONCLUSION

The results prove convincingly that the Technology allows maintenance of the natural conditions of the oil field for a long period of time. It prolongs the production life and maximizes the total oil recovery.

The Technology was tested during the past ten years in seven oil fields. The extensive statistical data shows that the increase in oil production was 20-25% on average, and that the payback period is two to four months. Compared to any other methods, where the payback period is measured in years, this is an exceptionally high result.

Additionally, as it is shown above, the Technology can be used within all geological structures.

TECHNICAL CONTRIBUTIONS

1. The Technology does not require any water and chemical injections or other stimulation operations.
2. The Technology affects the reservoir fluid, and due to the alteration of its physical properties, the percentage of oil within the extractable liquid increases significantly.

3. The Technology prevents water encroachment from the external sources, and, thus, decreases the watercut.

4. The vibrational impacts aimed at the certain points in the oil field cause the redistribution of the stress field within the reservoir rock along with the production stratum. This causes its partial restructuring, an intensive seismic emission, and, as a result, the emergence of new drainage areas. In particular, the tension of the reservoir rocks occurs within the pay zone and opens the compressed pores.

5. The effect of vibrational forces decreases the oil viscosity and increases the filtration processes dramatically.

6. The Technology impacts the finely dispersed reservoir zones of low permeability, and releases the great volumes of immobile oil.

7. The Technology is very environmentally friendly.

8. The Technology employs seismic vibrations generated at the surface.

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ILLUSTRATION CAPTIONS

1. Figure. 1. The oil production alteration of the Kala and Old Kala oil fields in tons (January, 1993 – August, 1996).

2. Figure 2. Map of the surface level change on the I and II cycles data (scale 1 : 50000).

3. Figure 3. The liquid production alteration of the Kala and old Kala oil fields (November, 1995 – February, 1996).

4. Figure 4. The reservoir pressures level difference between January, 1997 and November, 1996.

5. Figure 5. The difference in milligals of the gravitational field levels before and after influences.

6. Figure 6. The earth surface levels' changes map after influences conducted.

7. Figure 7. The relative seismic noise levels' changes (in %) after test influence (f = 0.5 – 20.0 Hz).

8. Figure 8. The reservoir pressure alteration (December, 1996 – May, 1998).

9. Figure 9. The reservoir pressure alteration (December, 1996 – May, 1998).

10. Figure 10. The reservoir pressure alteration (April, 1997 – May, 1998).

11. Figure 11. The water cut alteration in the wells of the Pervomayskoye oil field (January, 1988 – June, 1998).

12. Figure 12. The water cut alteration in wells of the Bondyujskoye oil field (January, 1988 – June, 1998).

13. Figure 13. The oil production alteration of the Pervomayskoye oil field (blocks 3, 4) in ton (January, 1988 – July, 1998).

14. Figure 14. The oil production alteration of the Bondyujskoye oil field (Central and South blocks) in ton (January, 1988 – July, 1998).

15. Figure 15. The oil production alteration of the Pervomayskoye, Bondyujskoye and Komarovskoye oil fields (January, 1988 – July, 1998).

16. Figure 16. The oil production alteration of the Pervomayskoye, Bondyujskoye and Komarovskoye oil fields (January, 1988 – July, 1998).

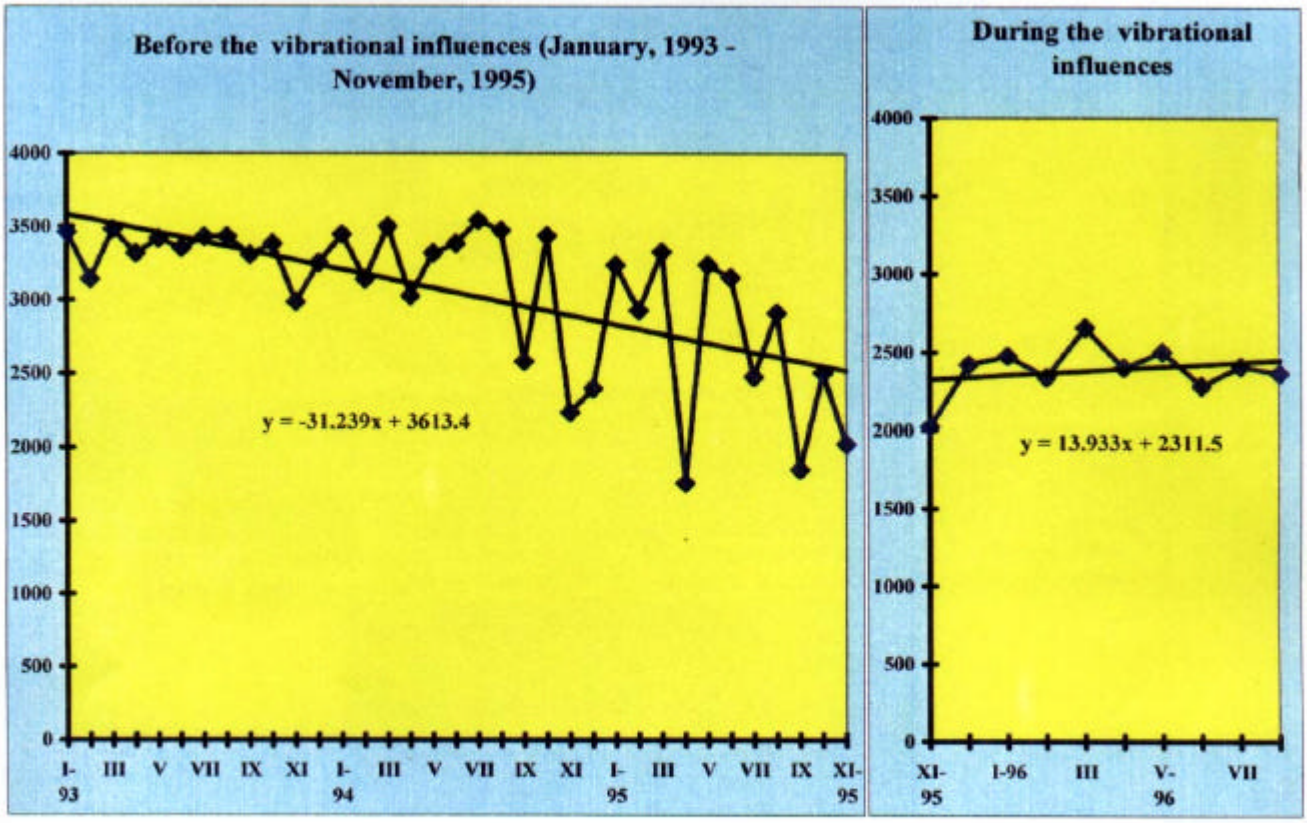


Figure. 1. The oil production alteration of the Kala and Old Kala oil fields in tons (January, 1993 – August, 1996).

MAP

OF THE SURFACE LEVEL CHANGE ON THE I AND II CYCLES DATA (SCALE 1:50000)

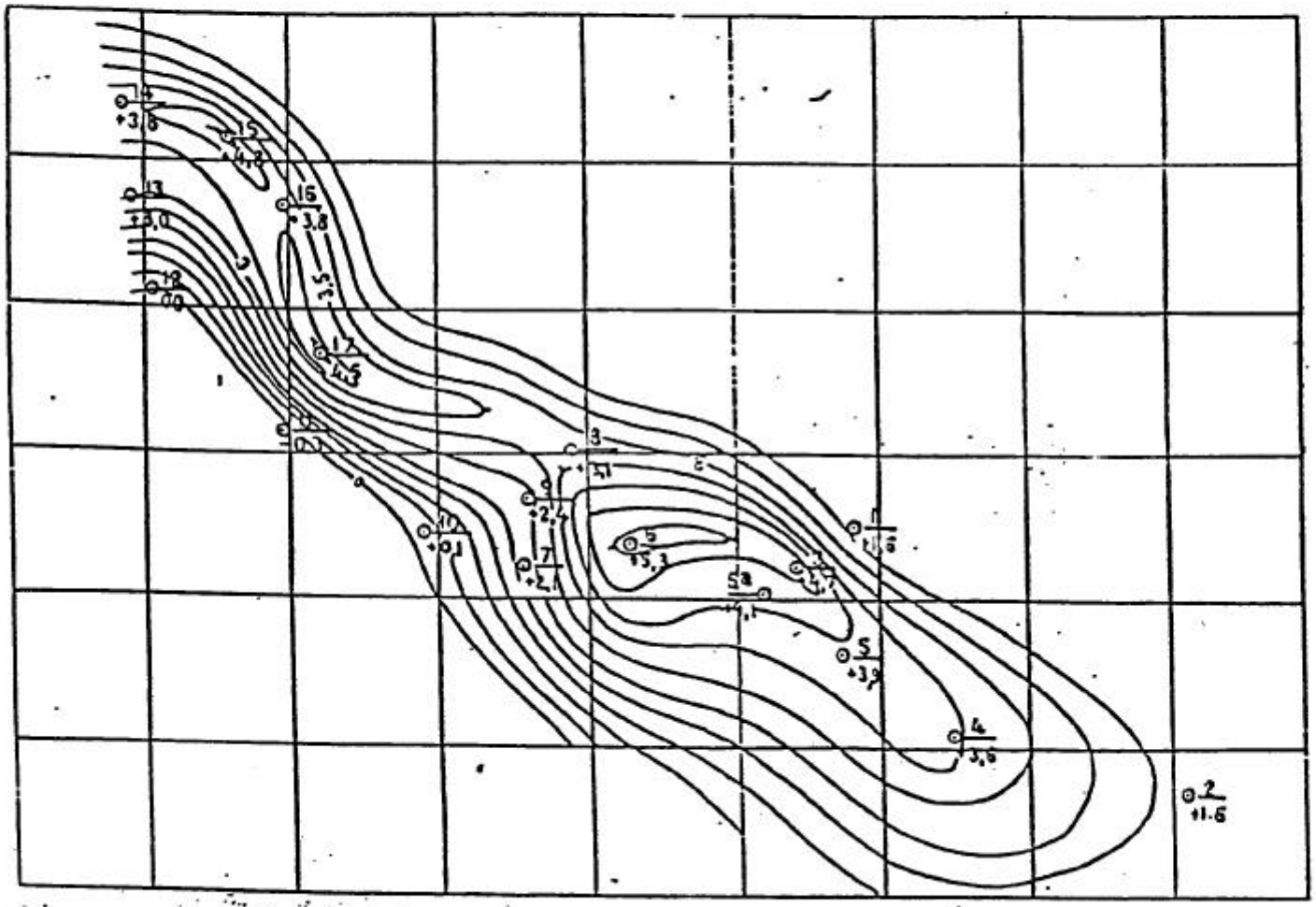
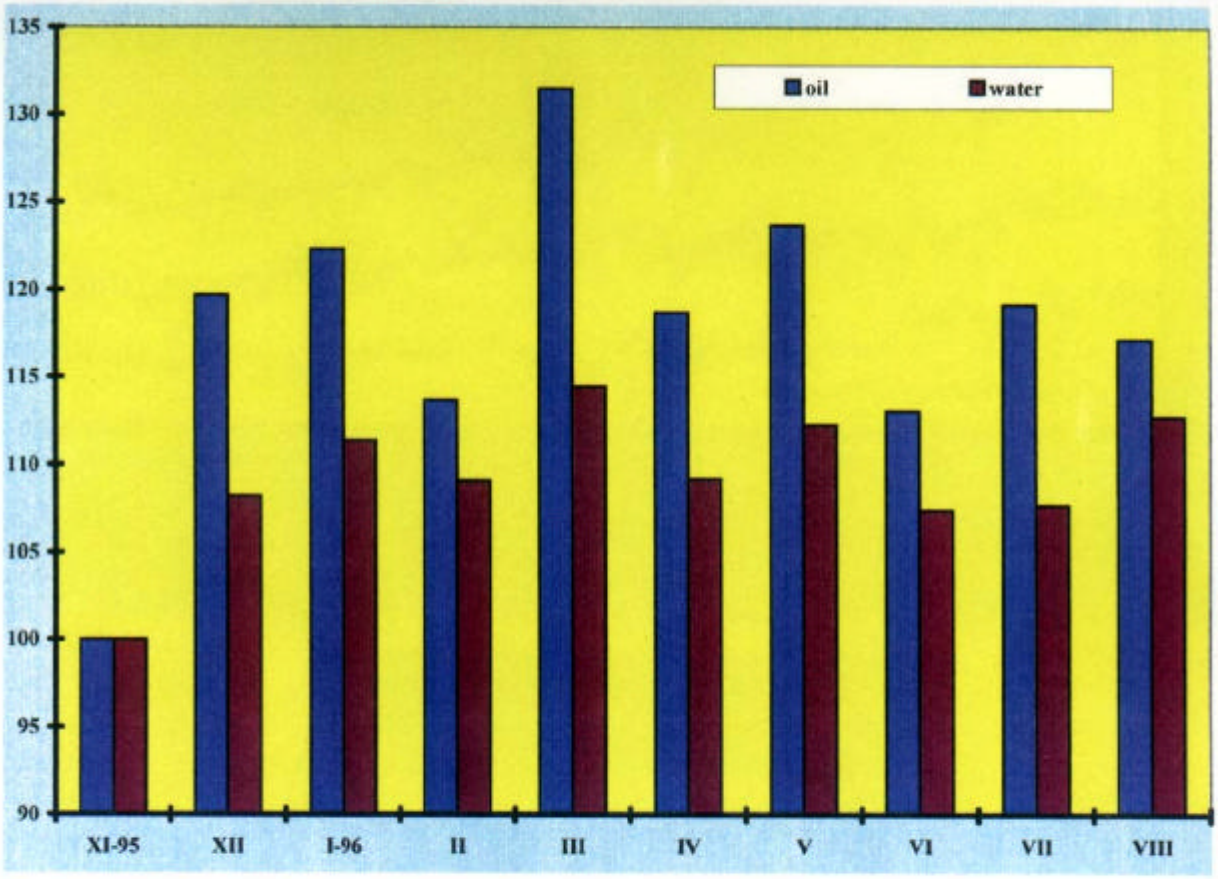


Figure 2



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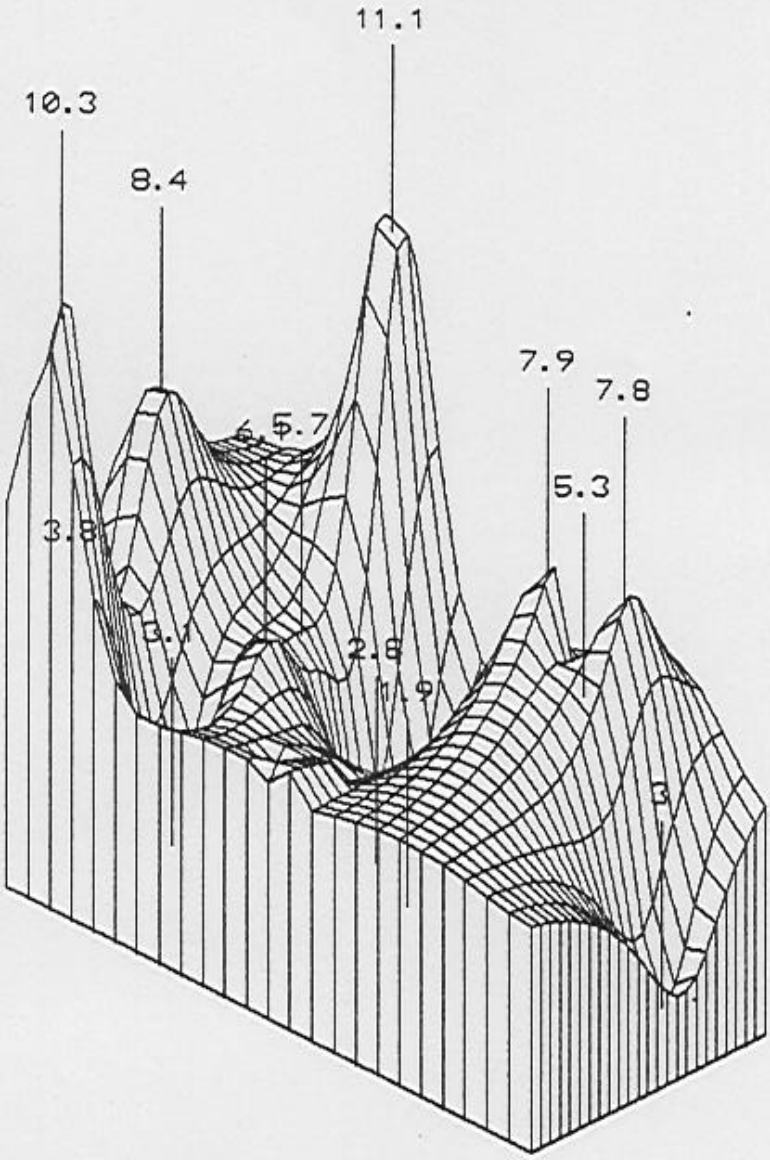


Figure 4. The reservoir pressures levels difference between January, 1997 and November, 1996

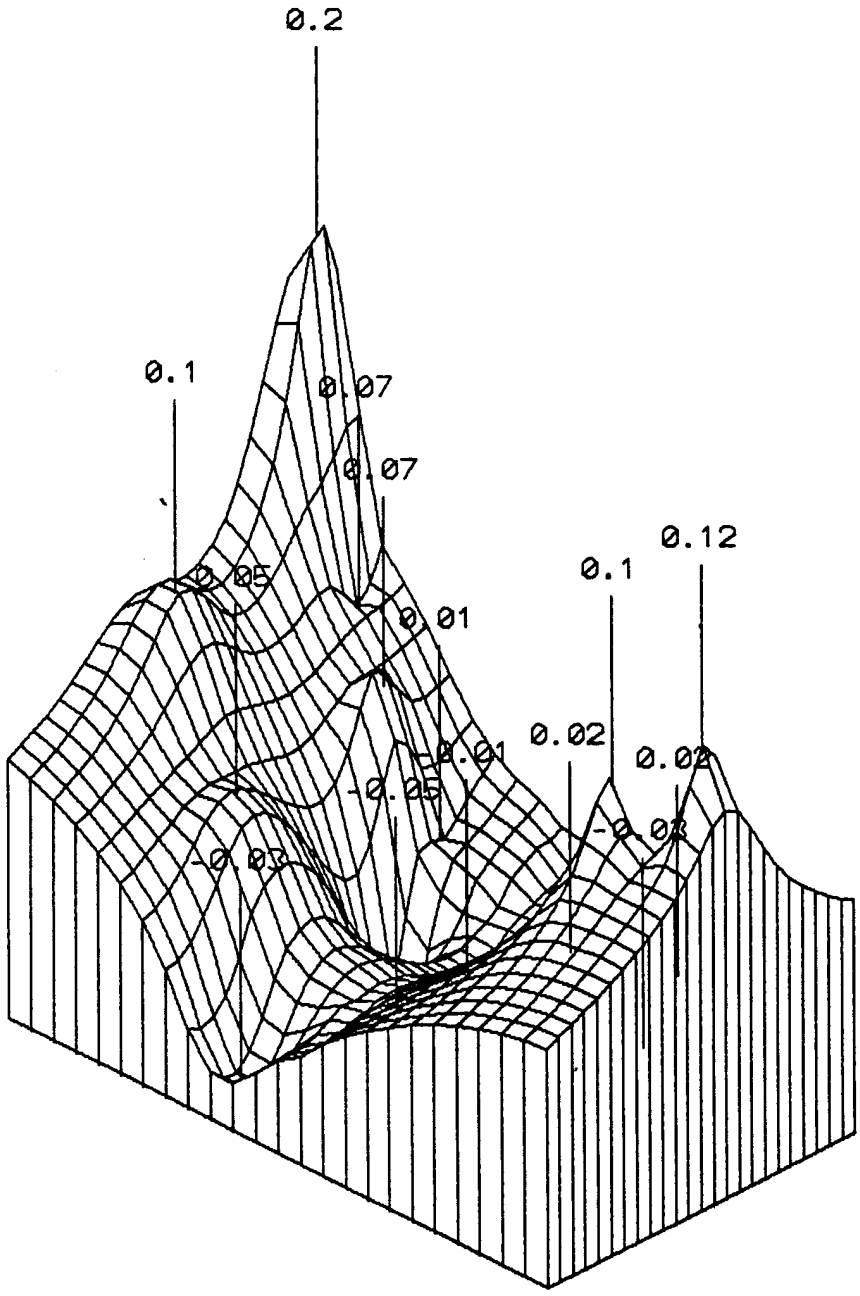


Figure 5. The difference in milligalls of the gravitational field levels before and after influences

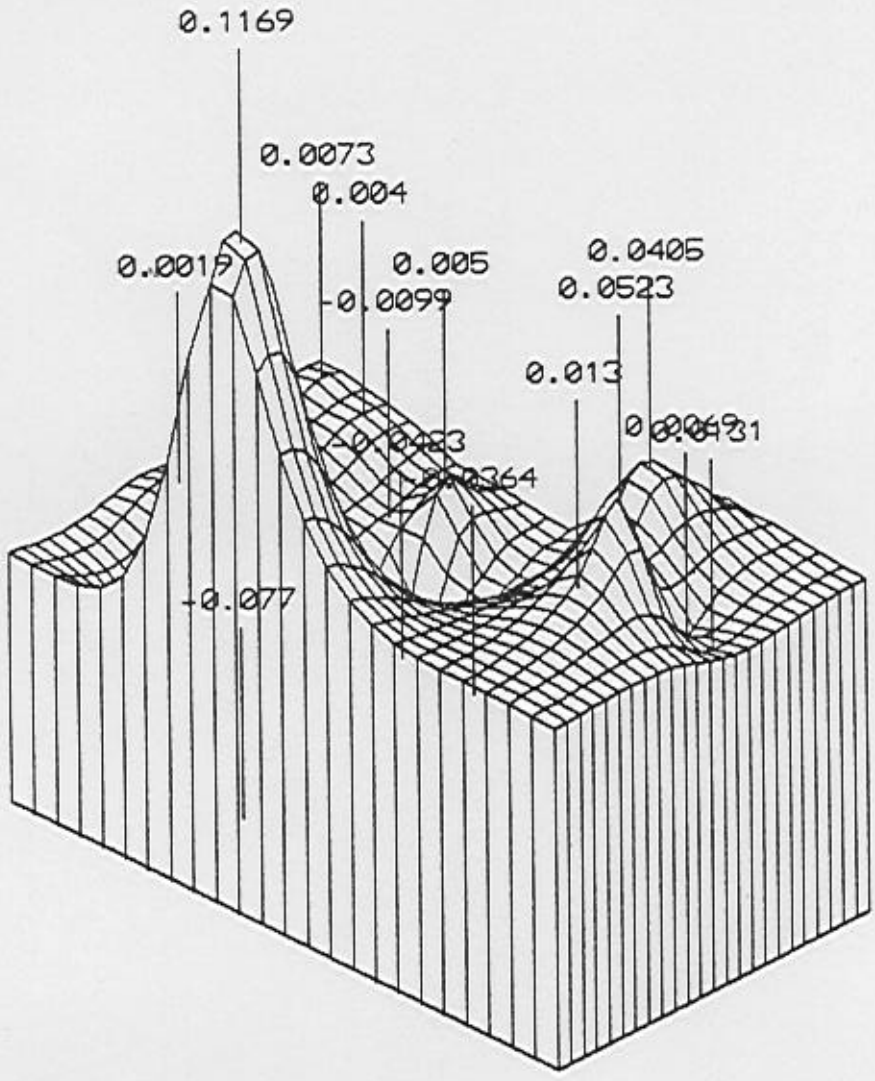


Figure 6 The Earth surface levels changes map after influences conducted

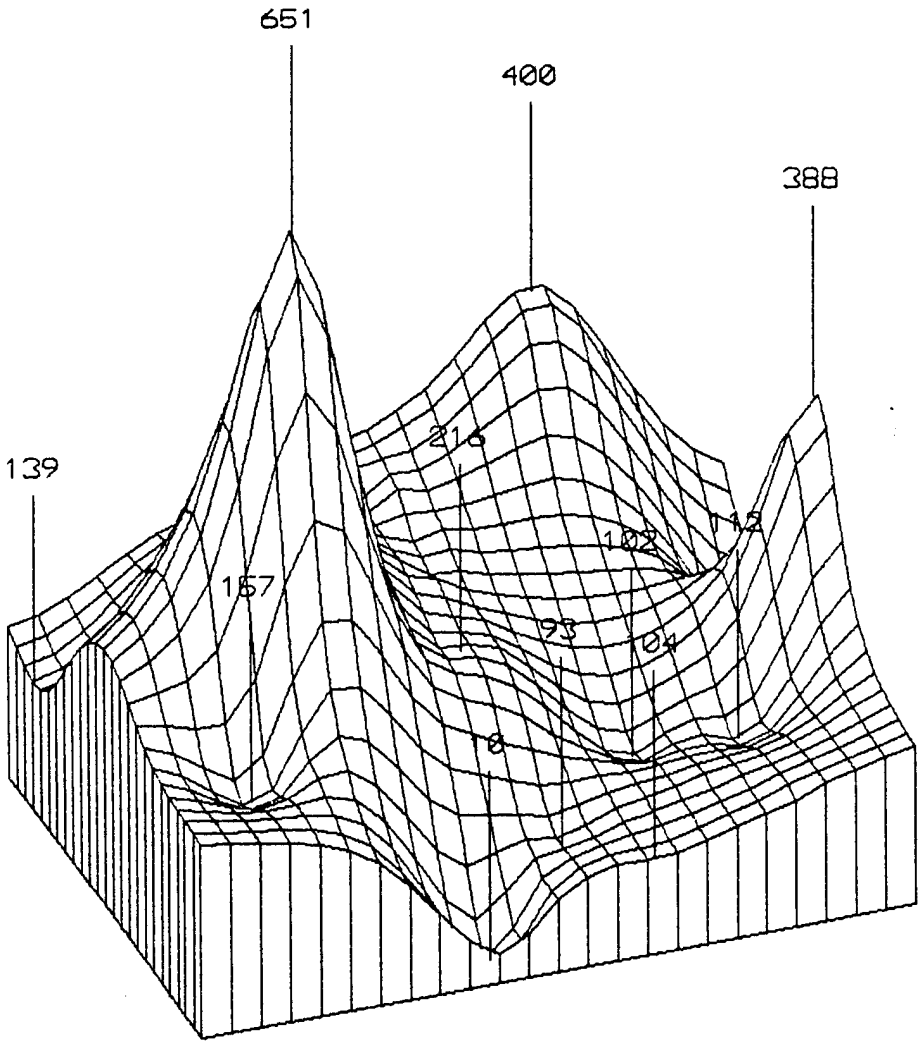


Figure 7. The relative seismic noise levels changes (in %) after test influence (f = 0,5 - 20 Hz)

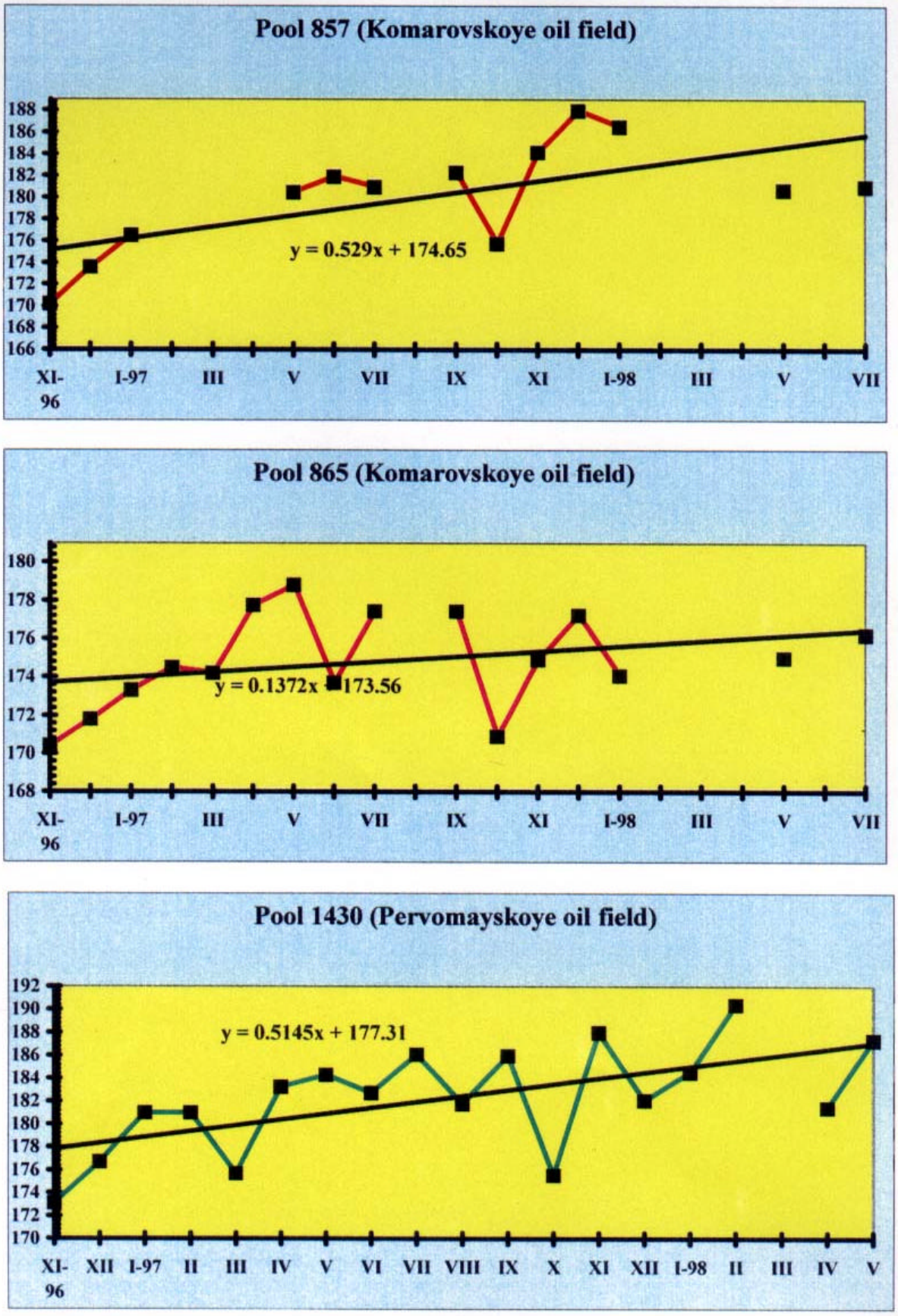
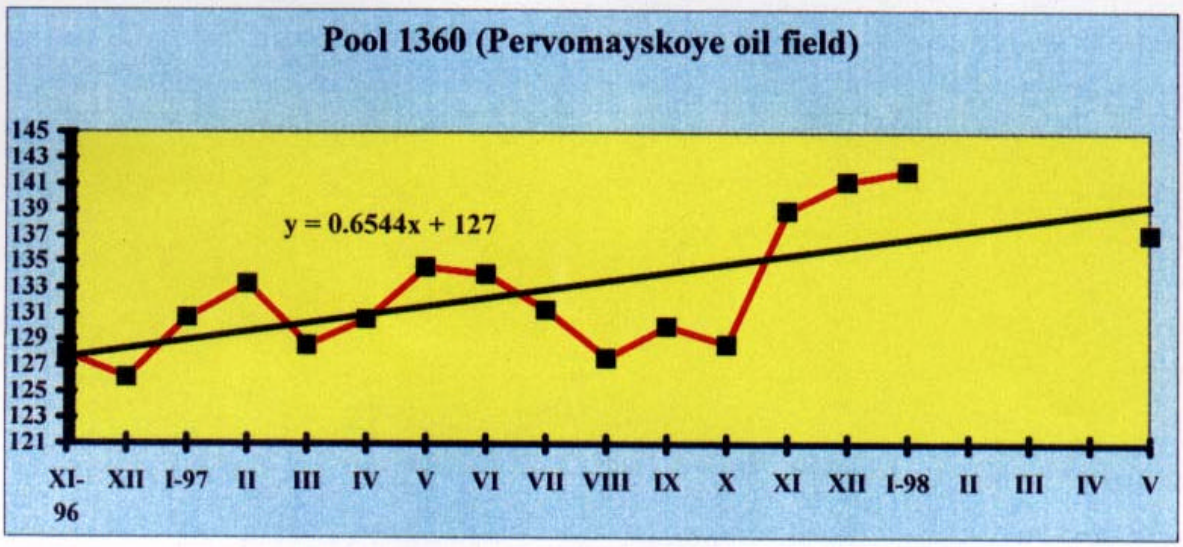
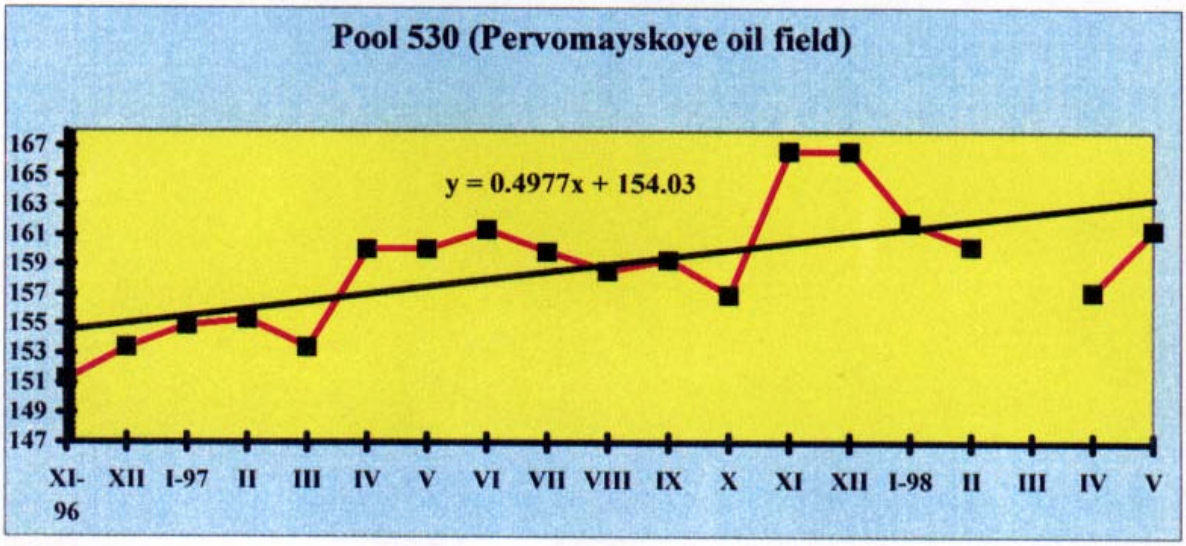
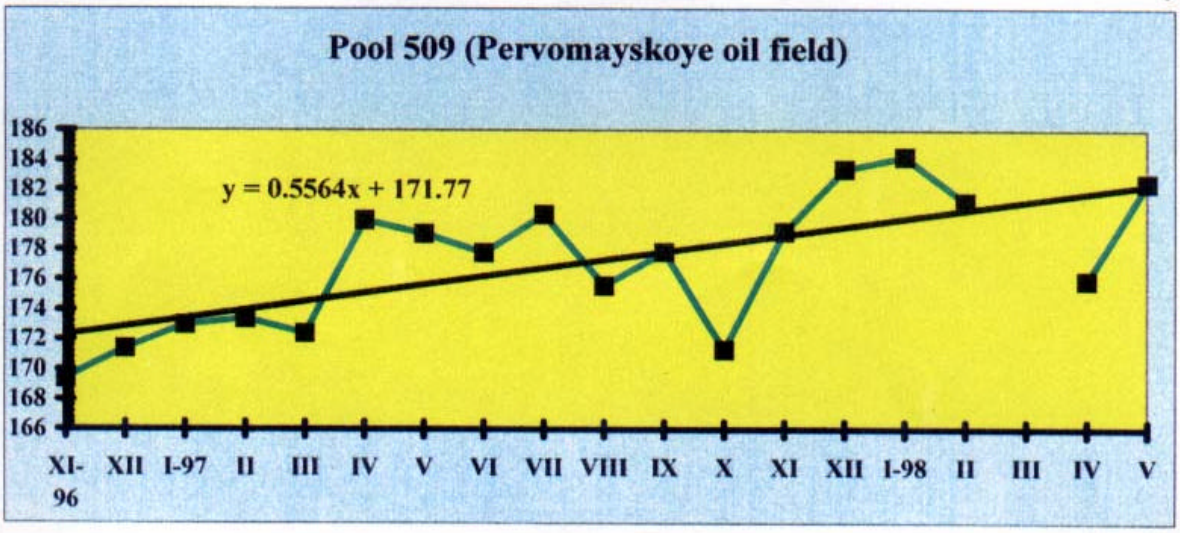


Figure 8. The reservoir pressure alteration (December, 1996 – May, 1998).







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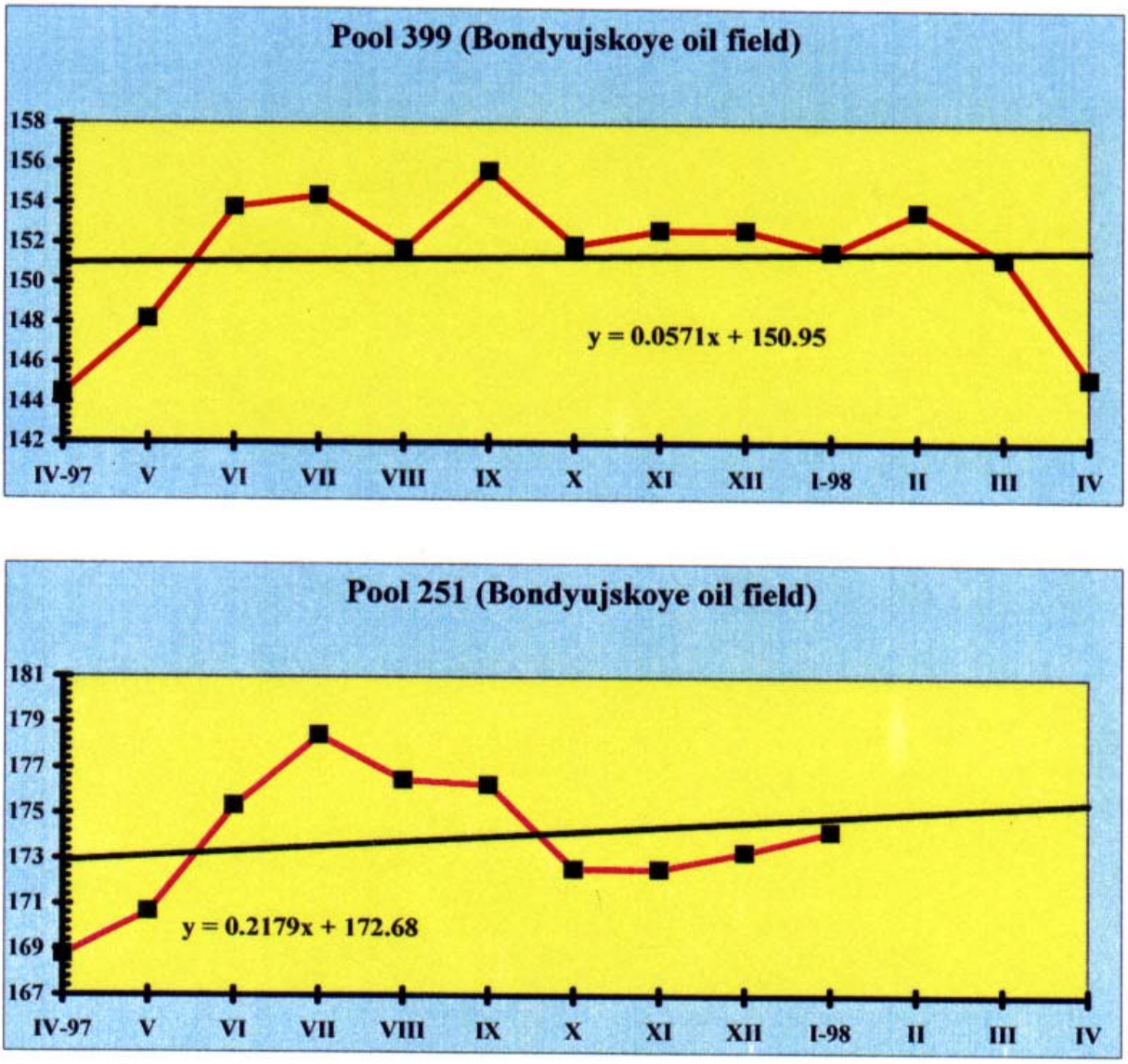


Figure 10. The reservoir pressure alteration (April, 1997 – May, 1998).

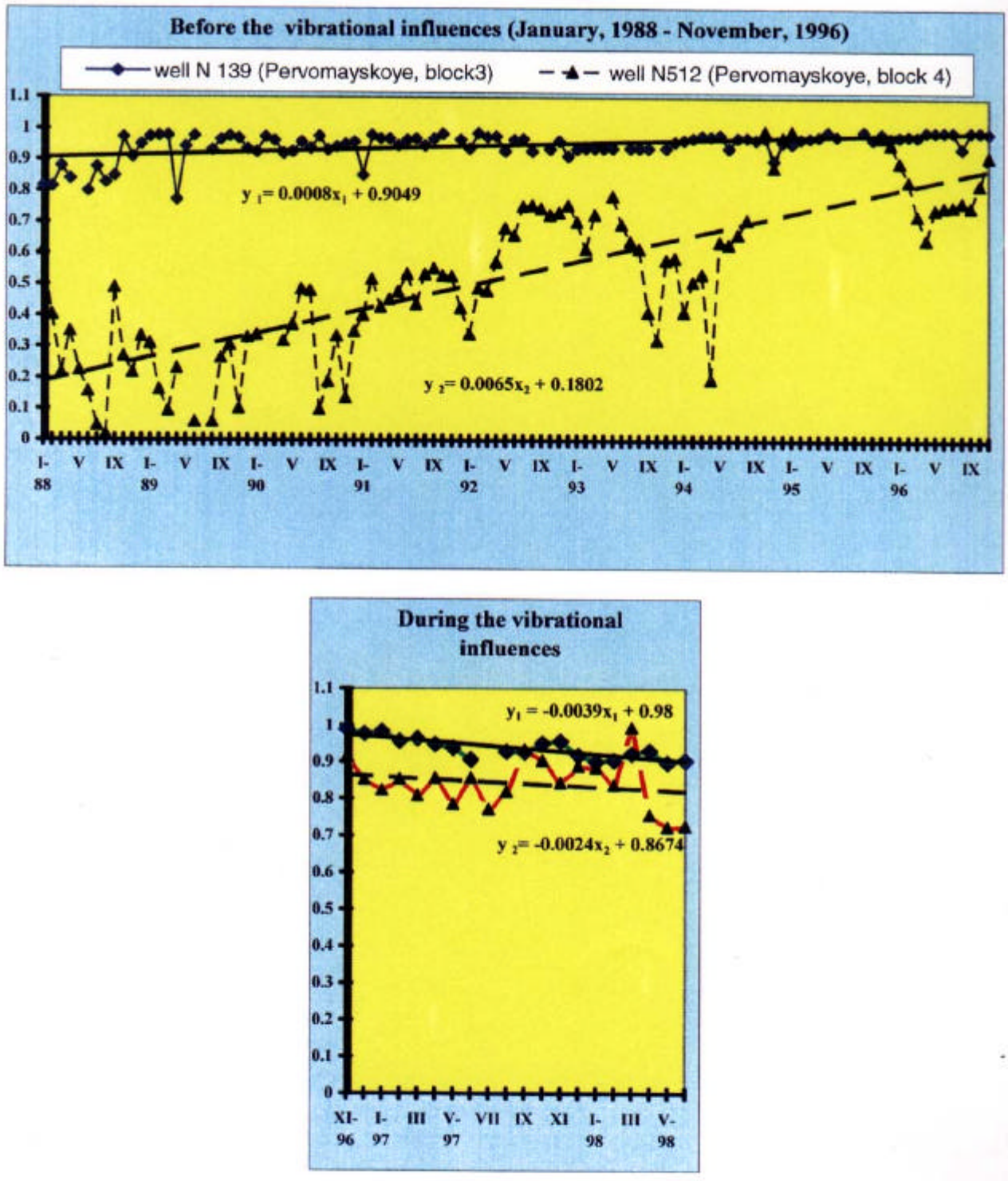
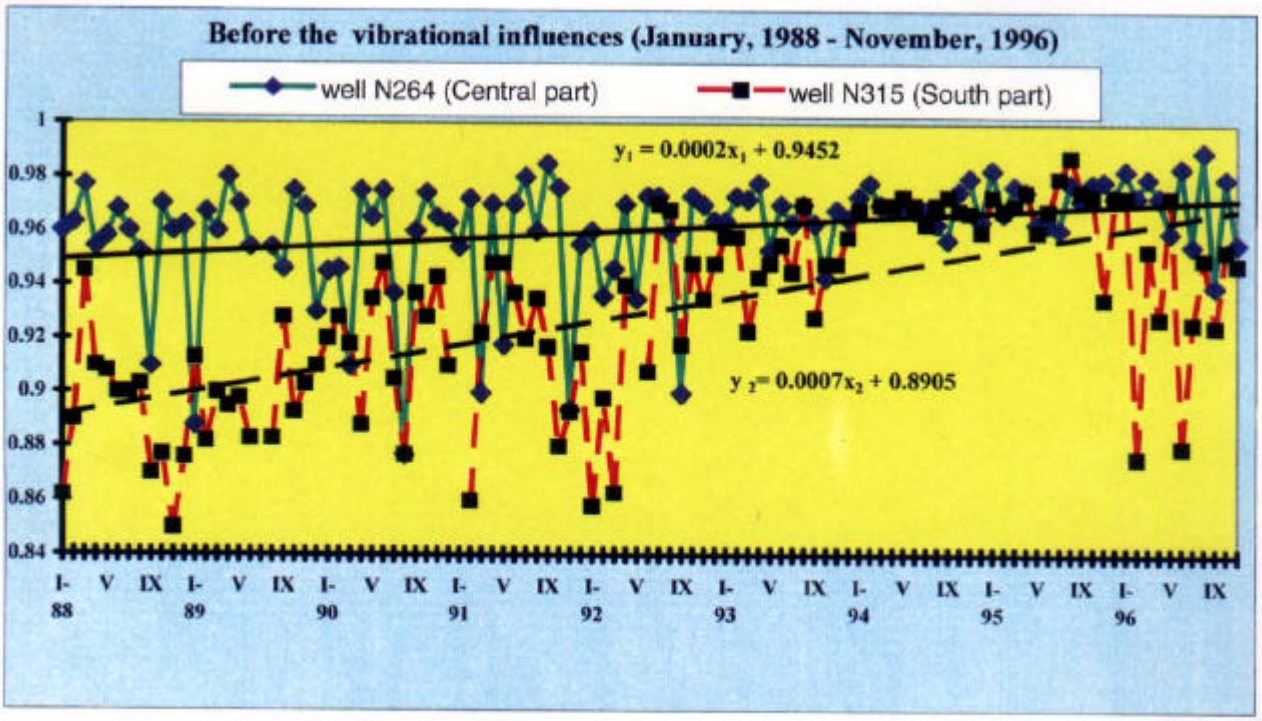


Figure 11. The water cut alteration in the wells of the Pervomayskoye oil field (January, 1988 – June, 1998).



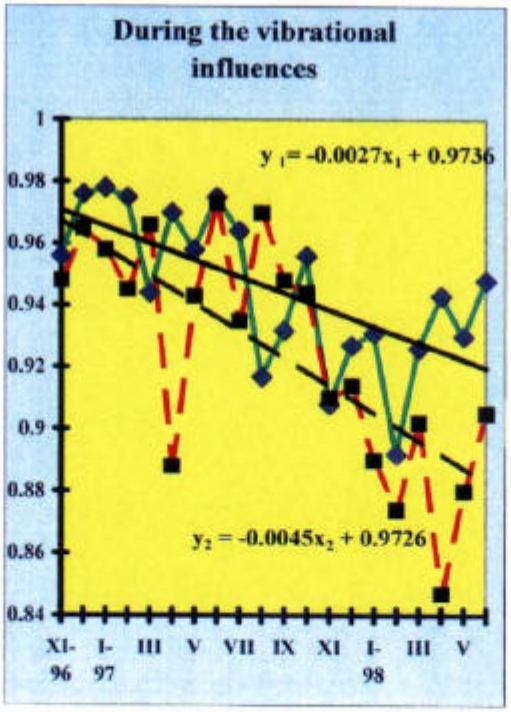
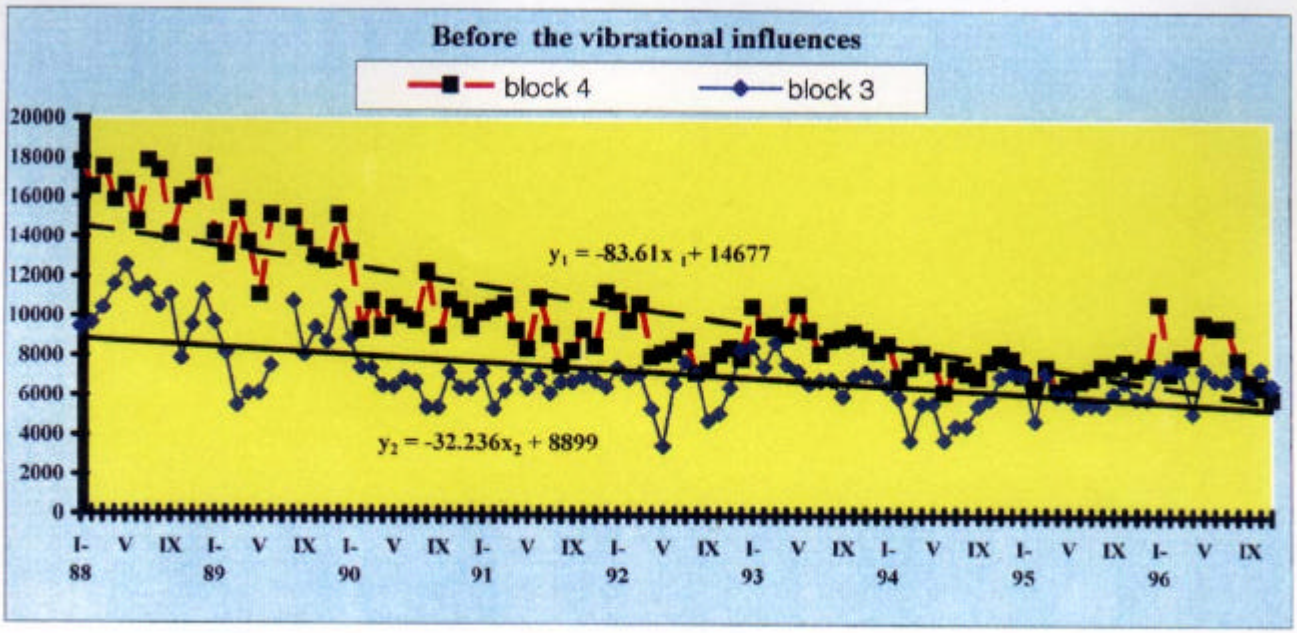


Figure 12. The water cut alteration in wells of the Bondyujskoye oil field (January, 1988 – June, 1998).



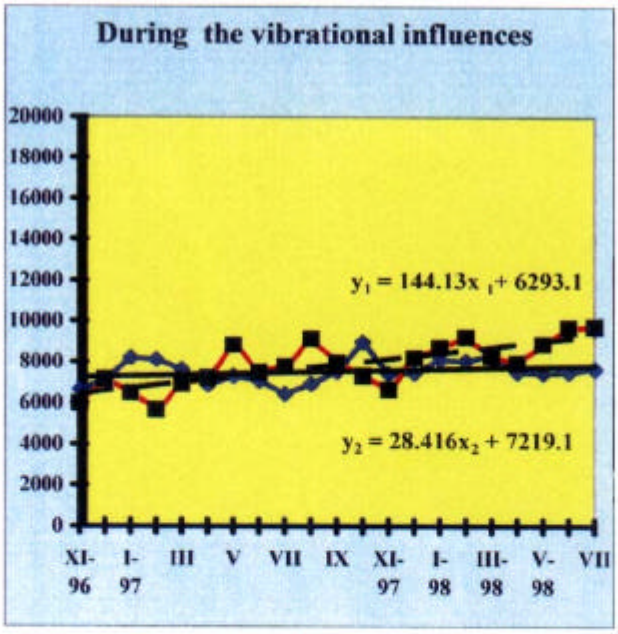


Figure 13. The oil production alteration of the Pervomayskoye oil field (blocks 3, 4) in ton (January, 1988 – July, 1998).

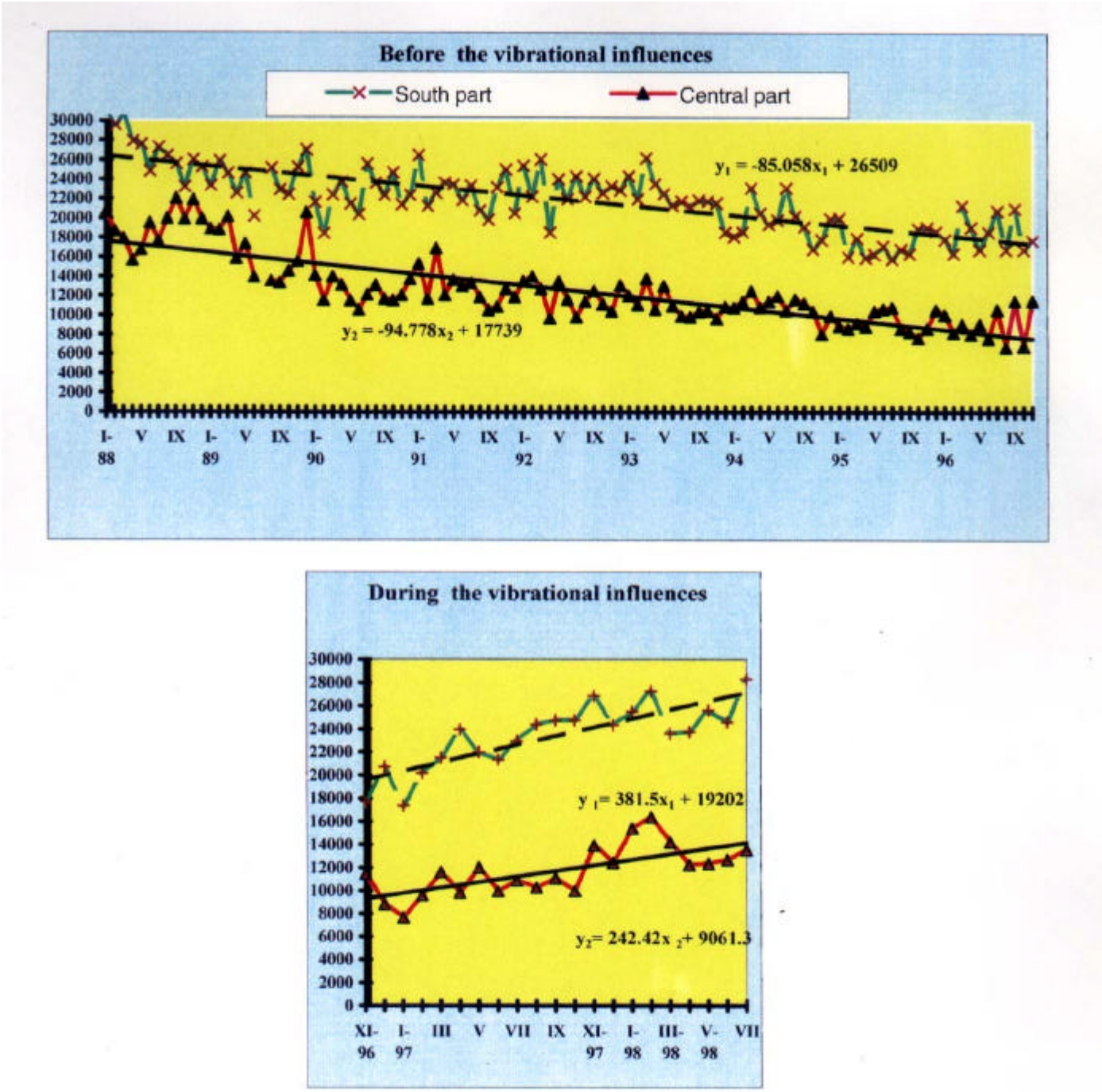
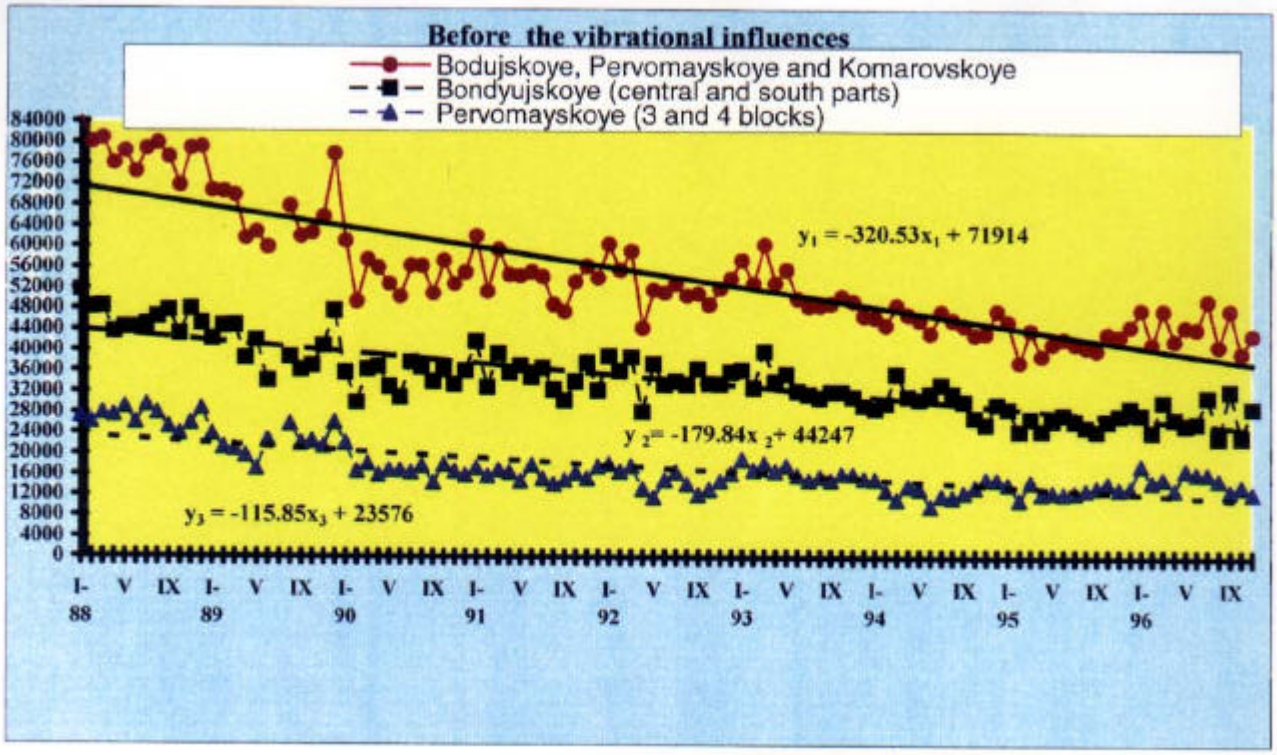


Figure 14. The oil production alteration of the Bondyujskoye oil field (Central and South blocks) in ton (January, 1988 – July, 1998).



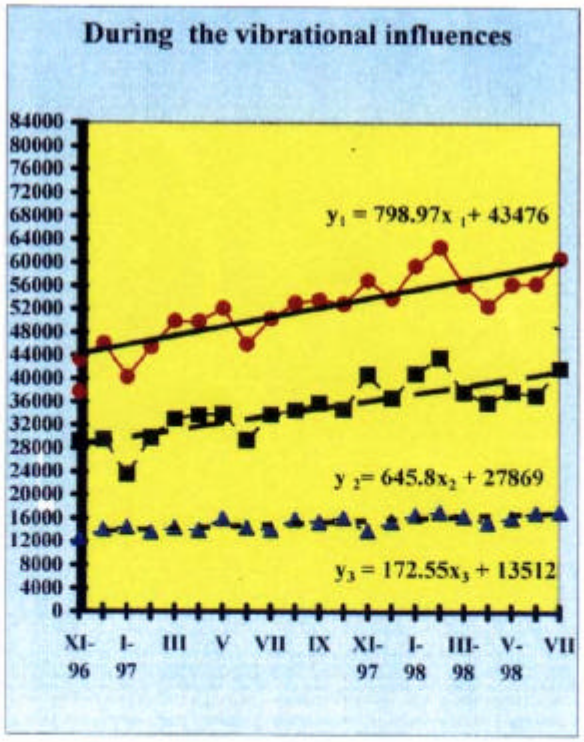


Figure 15. The oil production alteration of the Pervomayskoye, Bondyujskoye and Komarovskoye oil fields (January, 1988 – July, 1998).

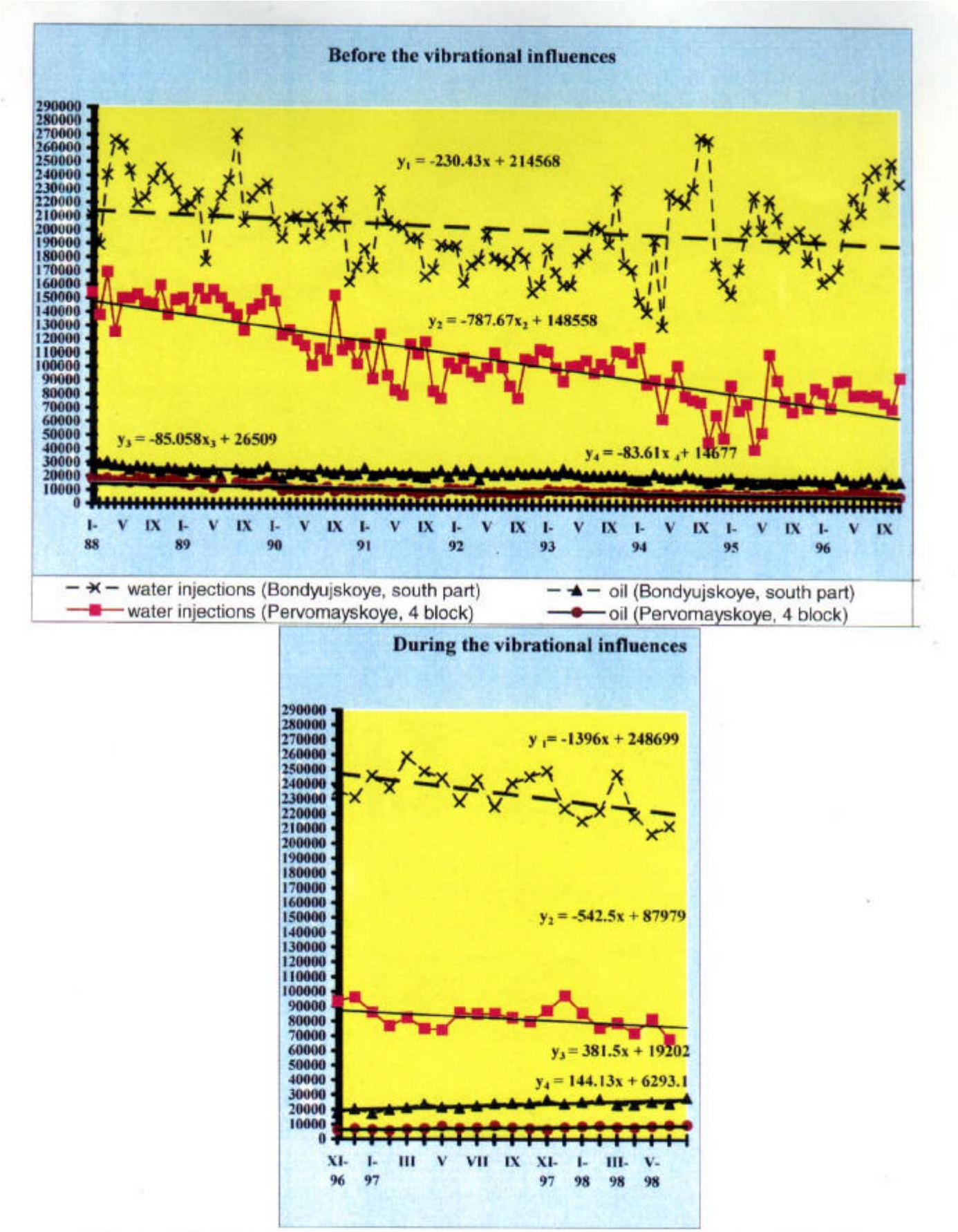


Figure 16. The alteration of the oil production and artificial flooding of the Pervomayskoye (block 4) and Bondyujskoye (South block) oil fields (January, 1988 – July, 1998).