

Environmentally correct oil fields development - the basis of their protection and enhanced oil recovery.

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Abstract: The problems of correlations between intensive oil field exploitation and seismic processes have been analyzed in this paper. The necessity and importance of seismic control of the induced effects caused by industrial activity in order to exclude negative ecological consequences and economic wastes is emphasized. Analysis of the development of seismic process at Apsheron-Cheleken threshold of Caspian Sea, where the main oil-fields of Azerbaijan are situated, shows that high level of stress state of medium in the region is caused by intensification of oil extraction. This factor leads to disturbance of geodynamical balance, increasing of seismic activity and considerable downfall of oil extraction's level.

Investigations have been evolved in three main directions.

The study of variations of the weak high-frequency wave fields, which led to the identification of previously unknown patterns of their changes in pre-earthquake period, i.e., in the process of stress accumulation in the medium, variations in their amplitude and frequency features ratio in time. It was shown that the seismic emission caused by the processes of preparation, happen almost at any distance from the focus of the earthquake and leads to significant changes in stressed medium condition. Identification of this pattern has been recognized as a scientific discovery.

Studies of the allowable loads on the medium, which do not lead to irreversible deformation processes. They were held on the examples of changes in reservoir pressures in different horizons of Starogroznensk deposits under the impact of preparation processes of two closely spaced earthquakes. The first occurred at the distance of 300 kilometers to the north, the second – at the distance of 220 km to the south of the deposits. We display the table of these changes, indicating that the underlying horizons (wells 5, 19) “felt” 9-17 months prior to its occurrence. Gradients of increase in the reservoir pressure were 1-2 atm monthly. Then the oscillatory processes covered higher horizons for 7-10 months prior to the earthquake, but their energy was much higher, so the gradients of increase in the reservoir pressure grew significantly, reaching the level of about 5 atm.

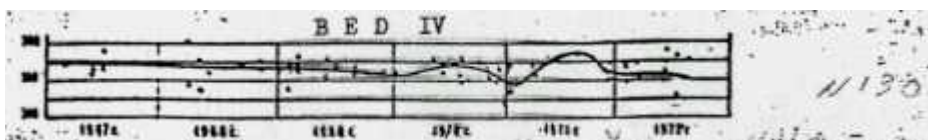
After the first earthquake processes in the medium started to attenuate, but never reached the background level, when the impact of the second event preparation processes commenced. Therefore, as seen from the table, all the horizons, which were still in the oscillatory process, almost simultaneously “felt” these changes, and increase in the reservoir pressures occurred with similar gradients.

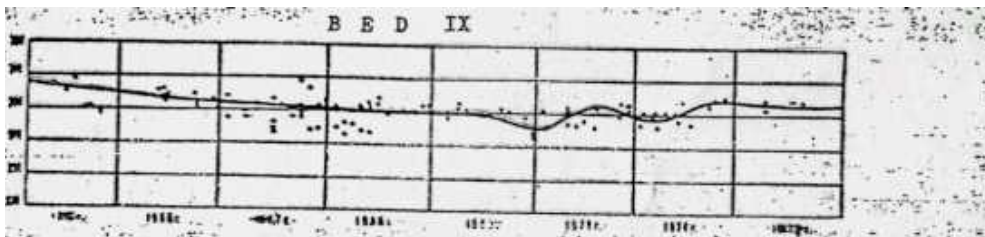
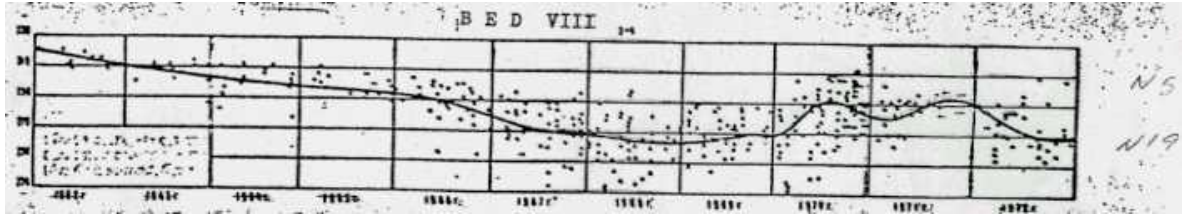
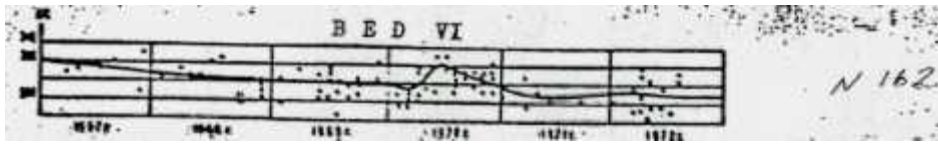
The conclusion that we have made on the basis of the above data analysis was as follows: limits of the allowable loads (drops in reservoir pressures) should not exceed 28-35 atm. In this case all the deformation processes are the linear. Exceeding these values results in a nonlinear deformation, plastic flow, occurring of vibration fields, and other effects that negatively impact on the condition of deposits, layer properties of reservoirs and to production. Previously we proposed the mandatory implementation of seismological and geophysical monitoring of field development with the purpose of elimination of all unwanted interference to the National Oil Company of the Republic. This proposal was accepted in 1991, but, unfortunately, would be never implemented. As a result the medium under the bottom of the Caspian Sea was greatly intensified. Examples of this fact are given on the diagrams A and B. If the medium was intensified some way in 1996, only 3 months after the start of using the airgun, then in 1998 it took only 3-5 days!

Studies of the effect of incorrect oil fields development at the state of the medium and seismicity. Wrong tactic of oil fields development in the Azerbaijan sector of the Caspian Sea is also specific and good example of all the foregoing and negative impact on the medium caused by this tactic.

Thus, we have revealed the existence of interference between the wells, well groups and between fields. Wrong and ecologically incorrect tactic of the development of the largest field in the Azerbaijani sector of the Caspian Sea - Gunashli – led to the 15-37 percent decrease in production of the remaining onshore and offshore fields within a radius of 70-100 km. Continuously held hydrofractures with 150-200 atm pressure drop led to the above negative results.

Variations of stratum pressure at Kolodezskoye oil field under the two earthquakes impacts

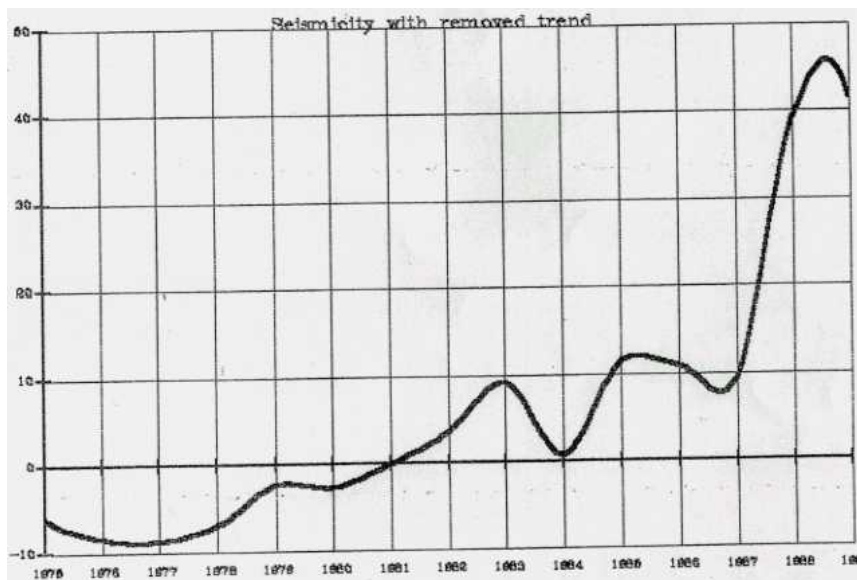




Table

N of well	The first earthquake				The second earthquake			
	T	ΔP		$\Delta P / T$	T	ΔP		$\Delta P / T$
	month	atm	%	atm/month	month	atm	%	atm/month
5	9	18.2	7	2	10	21.8	8	2.2
19	17	26	10	1.5	6	12	4	2
162	5	27	10	5.4	12	13	4	1
130	4	20	7	5	10	14	5	1.4

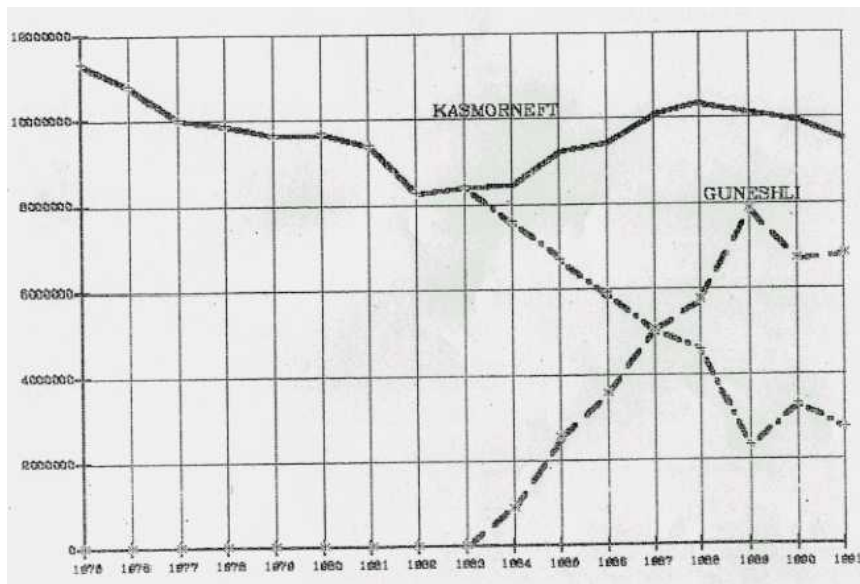
Seismicity changes in Caspian Sea from 1975 till 1991



The form of curve shows the tendency of the seismicity changes within Apsheron-Cheleken threshold. It should be noted that sharp change of seismicity begins in 1984-1985.

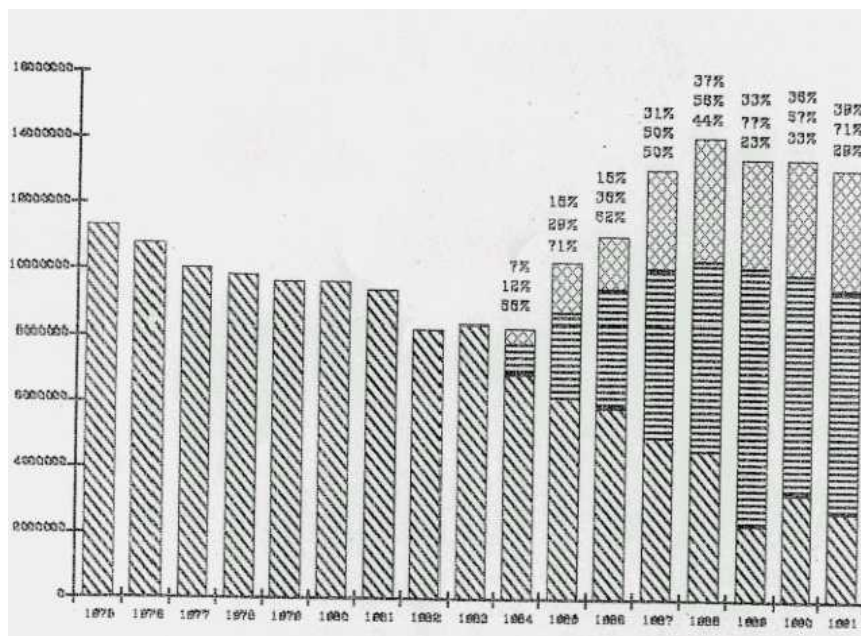
Intensive working of “Guneshli” oil-field as well as unsystematic exploitation of drilling holes lead to breach of natural balance of stress fields in medium, reactivation of old and activation of new earthquake zones, sharp increasing of seismicity of Apsheron-Cheleken threshold. All of that have a negative influence on physical parameters of oil-beds and stimulate appearance of high-stressed zones and correspondingly decreasing of oil extraction from other sea oil-fields of the region. These processes result in 20-30% decreasing of oil extraction and frequent accidents at oil fields are connected directly with increasing of seismic activity.

Oil extraction in Azerbaijan section of Caspian Sea from 1975 till 1991



This figure presents total amount of oil extraction (measured in million of tons) in 1975-1991 from sea oil-fields of Azerbaijan. Solid line describes total amount of oil extraction; dashed line – “Guneshli” oil-field; dot dashed line – all sea oilfields without “Guneshli” dot line-the curve modeled on condition that the rate of decreasing of oil extraction remain the same as before 1984. It is evident that volume of oil is continuously decreasing and just putting into exploitation in 1984 of a new oil-field “Guneshli” allowed to keep up oil extraction. Analysis of the curves of seismicity of Apsheron-Cheleken threshold and oil extraction of “Guneshli” shows their high correlation and testifies their close interconnection.

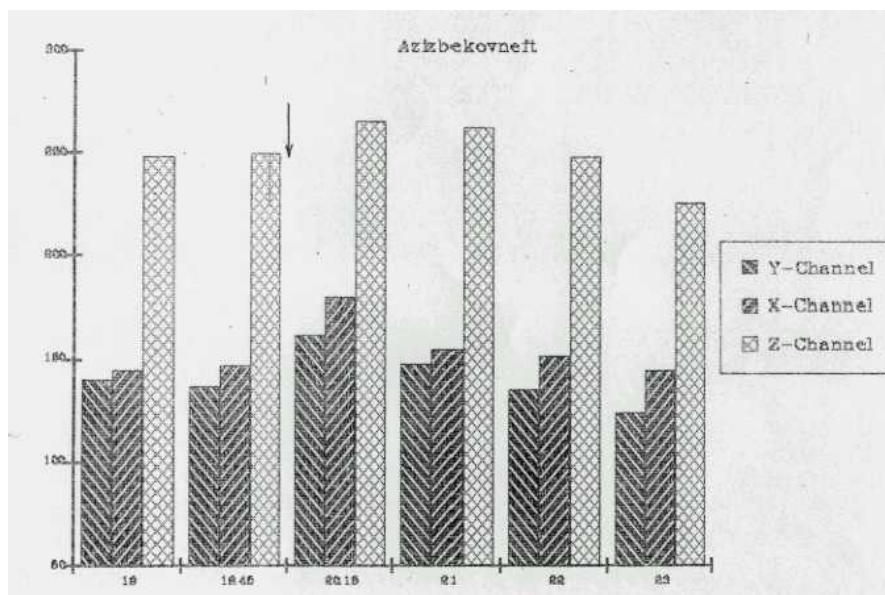
The diagram of the oil extraction in Azerbaijan section of Caspian Sea from 1975 till 1991 at the old oil fields and at the new oil field “Guneshli”



Percentage correlation of oil-extraction level in all sea oil-fields and losses of induced factors calculated according to worked out model.

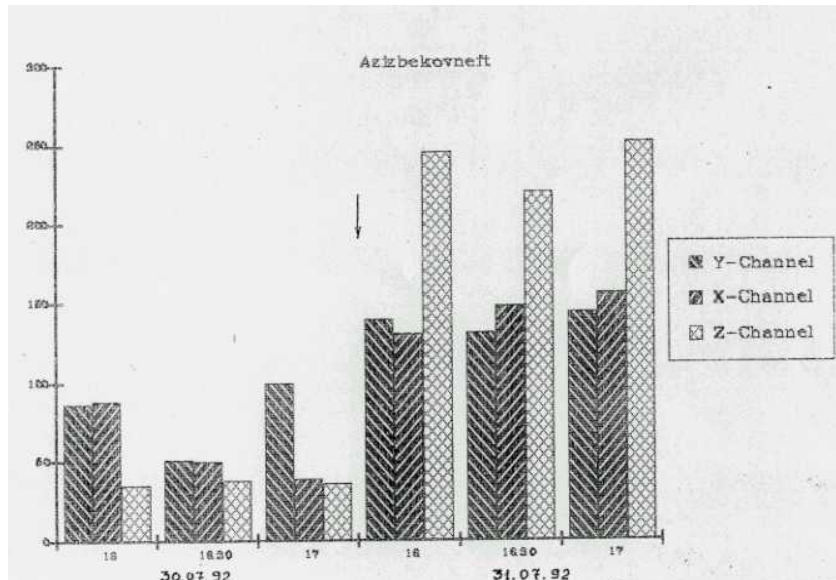
Our analysis have shown that at weak energy level geophysical medium manifests high dynamic activity and exceptional sensitivity to any external influence and even slight industrial activity can lead to considerable disturbances in the processes proceeding in it. We have experimentally found out the peculiarities of induced seismicity such as characteristic wave-form, dominant frequencies, and specific splashes of intensity and so on. That allows to reveal considerable contribution of induced effects to appearance of numerous high-stressed zones on Apsheron-Cheleken threshold.

The diagram of seismic emission at “Azizbekovneft” oil field after small seismic impact recorded by three component seismological station



The test impact done to check stressed state of the medium in and around oil fields. The diagram shows just small changing in seismic emissions which quickly came to the background level. But after more strong seismic impact the high level seismic emissions observed several days. These graphs prove the considerable level of stressed state accumulated in medium because of non-controlled oil field exploitation.

The diagram of seismic emission at “Azizbekovneft” oil field after strong seismic impact recorded by three component seismological station



Conclusion: We developed the Technology to increase oil production and recovery which helps to prevent any interferential and interactional impacts between wells, groups of wells and even between oil fields, helps to choose the better tactic for oil fields exploration to prevent their quick destruction and watercut.