Tracing Techniques Utilizing Radioactive Isotopes

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One of the scientific advances brought about by the cold war has been the development of techniques to measure extremely low levels of radioactivity. Analyses of upper air samples collected by U-2 type aircraft have yielded valuable intelligence information about the types of nuclear devices exploded by other nations. The techniques used to analyze such minute quantities of radiation are available to the petroleum industry and have many useful applications in reservoir engineering.

The use of tracers to follow movement of gas, oil, or water is not new. Underground tracer work has utilized many materials, among them certain dyes and chemical compounds, helium and carbon monoxide. The problems are the same in every application:

(1) To get the tracer to behave identically with the material traced
(2) To obtain adequate sensitivity
(3) To carry out the tracer project at reasonable cost

Differences in adsorption, absorption, wetting, precipitation, etc. between the tracer and the fluid to be traced cast doubt on the results on many of the earlier tests. These tracer techniques also lacked sufficient sensitivity. Such factors discouraged the use of tracing techniques, even though it has been obvious since the beginning of secondary recovery that an ideal tracer would be useful in almost every operation.

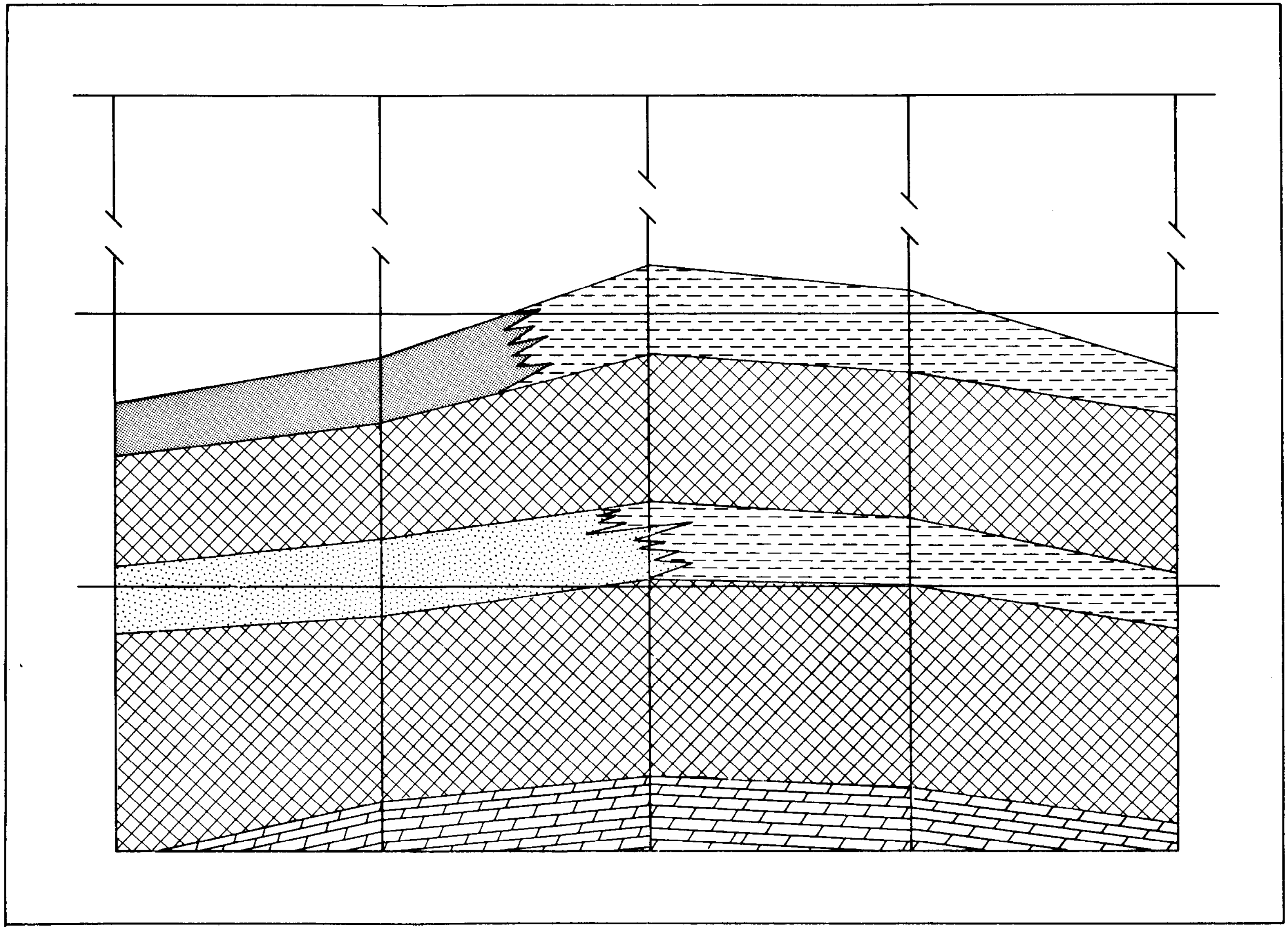
In principle, radioactive isotopes constitute ideal tracers; first, because the fluid itself may be made radioactive, or the tracer can be made a part of the fluid chemically. For instance, tritiated water acts the same as water because it is, in fact, a part of the molecule water. The only difference is that one of the hydrogen atoms in the H_2O molecule has been replaced by a tritium atom. Tritium is an isotope of hydrogen, having two extra neutrons in the nucleus. Tritium has a half life of 12.5 years, and low level counting techniques make possible the detection of these isotopes through seven half lives or approximately 85 years. A number of other low cost radioisotopes are available for use in water injection projects. Tritiated hydrogen, Krypton-85, and tritiated hydrocarbon gases may be used in tracing the movement of injected gas in a gas injection project. The development of extremely low level counting techniques, together with the decrease in the cost of radioactive isotopes, has made their use as tracing material practical. Furthermore, there are no siginificant health hazards involved in these applications.

The extremely large dilution factors in waterflooding and gas injection projects frequently preclude the use of dyes and chemicals. Even where dyes and chemicals can be used, the quantities necessary are frequently so great as to make the project uneconomical. The new techniques using radioisotopes readily permit dilution factors in order of 10^{13} to 10^{17}. It is now possible to determine one tritium atom in the presence of 10^{19} atoms of ordinary hydrogen. By injecting radioisotopes in the injection wells with the injected fluids it is possible to "tag" the injected fluid and, by analyzing produced water or gas, to trace the movement of the injected fluid throughout the reservoir. By "tagging" several injection wells with different tracers, a great variety of reservoir engineering information can be made available at a moderate cost. Premature breakthrough in producing wells has long been a problem in waterflooding and gas injection projects; now it is possible to identify the injection wells responsible for the breakthrough without the time consuming process of selectively shutting in injection wells. The flood front may be kept in balance to prevent premature watering out of producing wells. Directional permeability may be identified early in the life of the project so that steps can be taken to maximize recovery efficiency. Frequently, impermeable barriers and highly permeable channels can be located and identified by use of these techniques. In multi-zone reservoirs, multiple tracers can be used to determine communication between zones and the movement of injected fluid within the various zones. This is shown on Fig. 1.

Due to the diffusion of the tracer material with the injected fluid, produced water and gas from producing wells do not require constant monitoring in the field. A single pulse of radioactive material may be injected and become diffused so that the fluids produced will be slightly radioactive for a substantial period of time. This is shown on Fig. 2. A sample of produced fluids can be taken at intervals, generally monthly or semi-monthly, and stored until analysis is required. There are no health hazards involved in collecting and storing samples of produced water or gas, since the radioactivity level in this produced fluid is much less than the permissible level in drinking water. After breakthrough has been definitely established, the analysis of several samples should permit the determination of breakthrough time to within one week.

Secondary recovery projects have become more and more complex in recent years. With this increase in complexity, there has been an increase in the cost involved. Frequently, pilot projects produce results that are not indicative of conditions in the entire reservoir due to the lack of sufficient control and lack of interpretive data. This can result in a substantial loss rather than profit. The use of radioisotopes as a tracer in pilot projects as well as full scale projects can be invaluable because of the amount of information they provide at moderate cost. Figure 3 is an illustration of a five-spot pilot project in a reservoir having directional permeability. The permeability in northwest-southeast direction is four times as great as in the northeast-southwest direction, and as shown on Fig. 3, the areal sweep efficiency is quite low. By "tagging" the injection wells with four different tracers, this condition would be readily apparent and certain changes in pattern could be made prior to full scale injection to increase areal sweep efficiency and maximize profit. This is shown on Fig. 4.

Radioactive tracers have been used in water and gas injection projects in Texas, New Mexico, Oklahoma, Louisiana, Mississippi, and Venezuela. Results indicate that the use of radiotracers is an important new tool in reservoir engineering. It is now possible to obtain reservoir engineering information not available by any other means at a moderate cost. The operator can obtain information and identify problems early in the life of the project and make any necessary changes to maximize recovery efficiency and profitability of an injection project.



TRACER MOVEMENT IN CROSS-SECTIONS

FIGURE 1

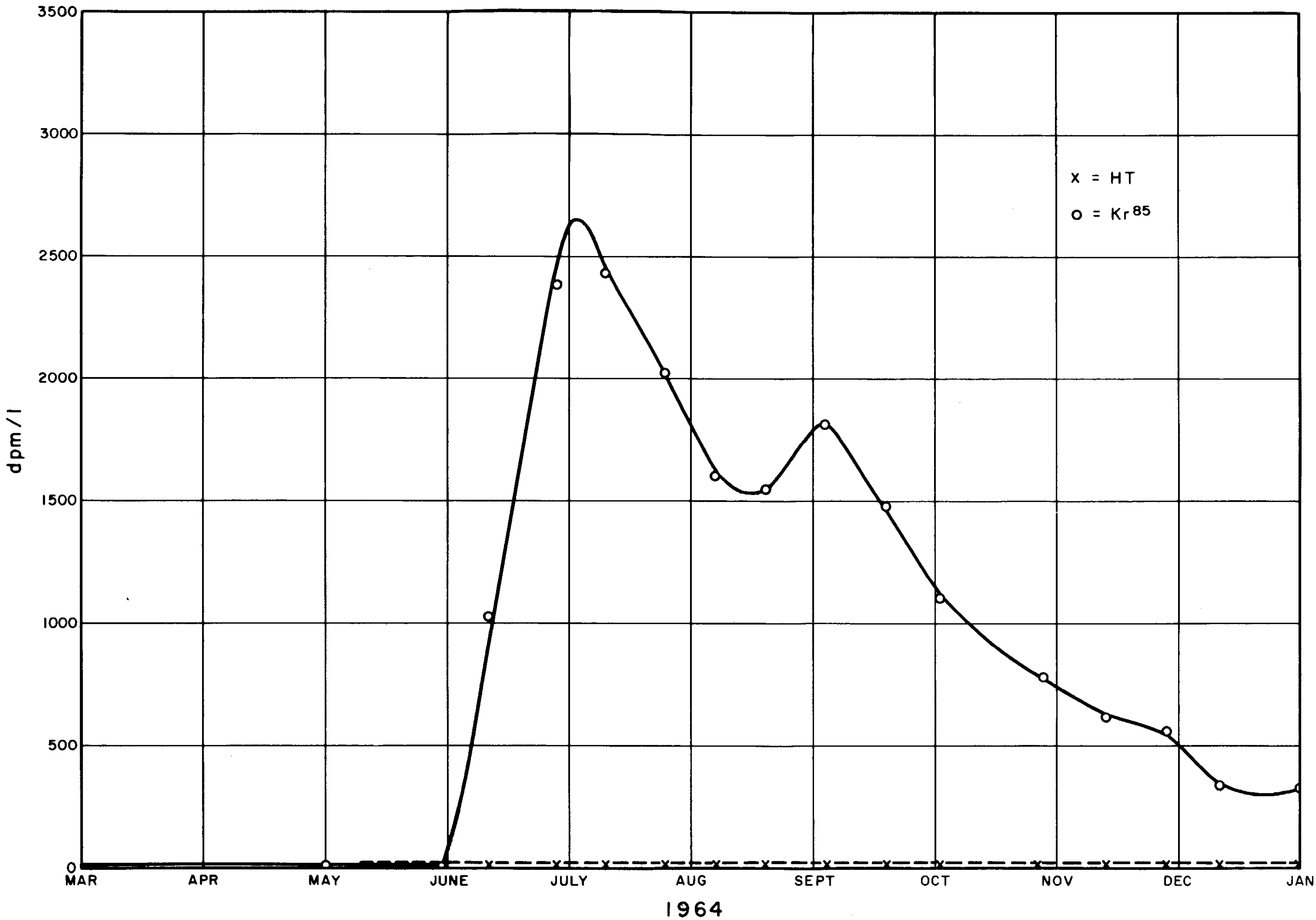

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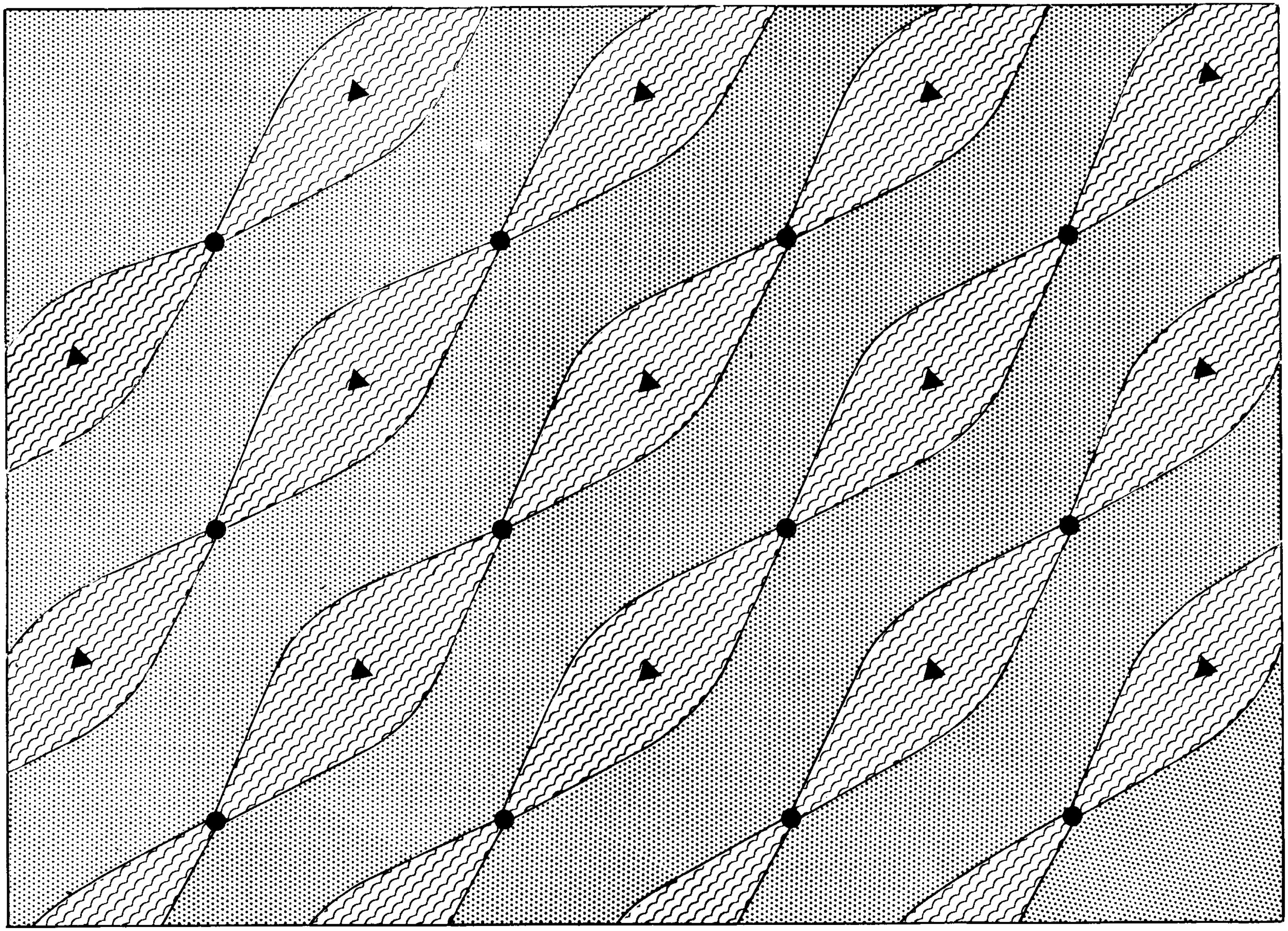
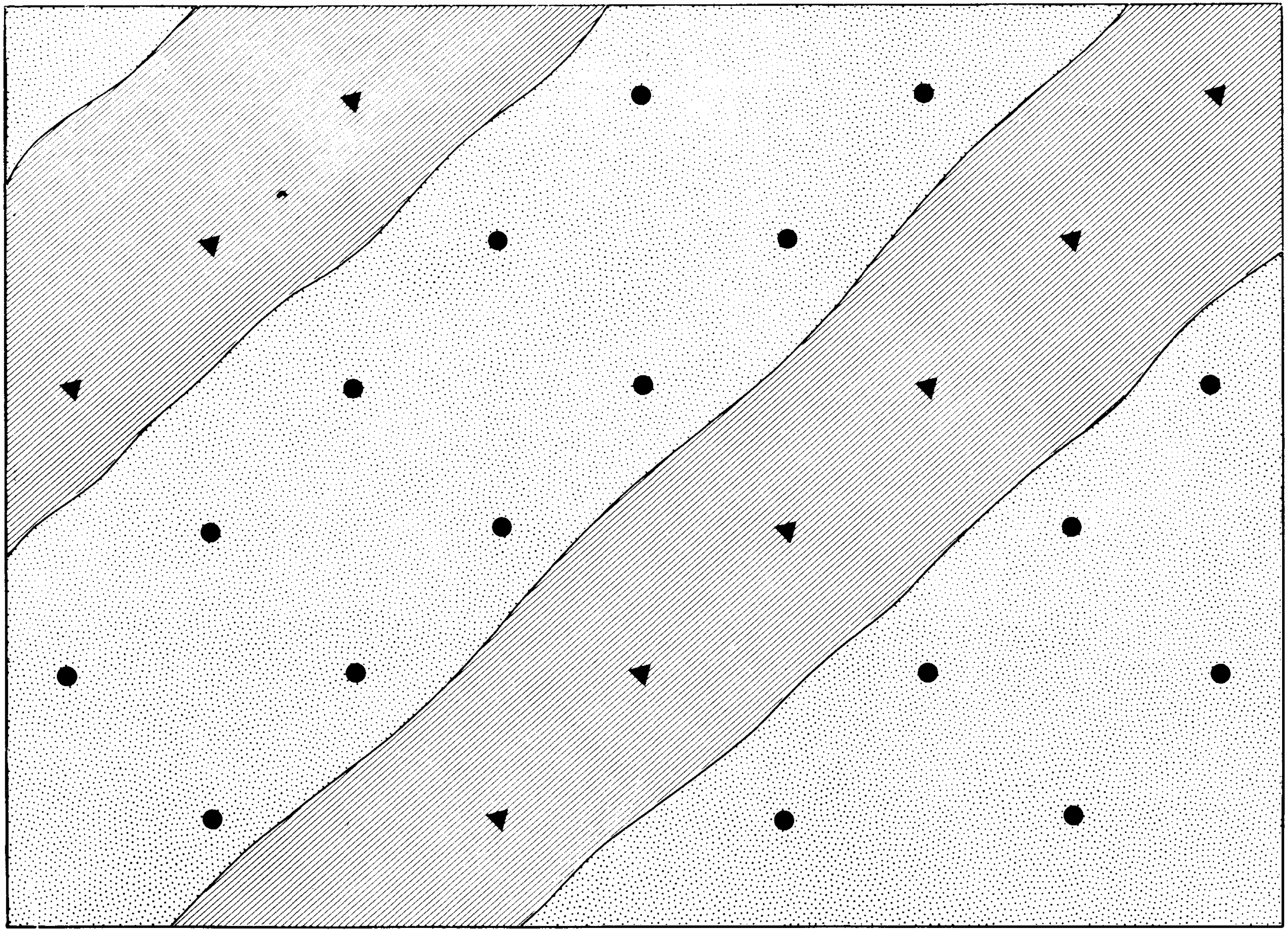
FIGURE 2



FIVE SPOT PATTERN

FIGURE 3



▲ INJECTION WELLS ● PRODUCING WELLS SWEPT AREA UNSWEPT AREA

LINE DRIVE PATTERN

FIGURE 4