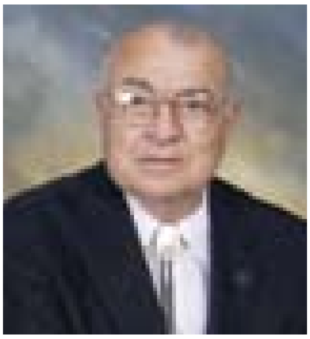
Geomicrobiology



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The ever increasing demand for oil, coupled with the reduction in reserves [1], is increasing emphasis on finding new oil deposits and recovering more oil from known reserves since half to two thirds of all of the oil discovered to date is still in the ground and not recoverable by present technology. There are, however, microbiological techniques that could be of value in extending the time before alternatives to oil as the major energy source are required. Two will be discussed here – geomicrobiological prospecting and microbial enhanced oil recovery (MEOR).

The use of microbiological technology to locate subterranean hydrocarbon deposits was first proposed by Mogilevskii in 1937 [2]. Since that time various modifications and permutations have been forthcoming. From a practical standpoint it might be well to consider some of the results obtained by using geomicrobiological prospecting. Subbota [3] reported that in Russia drilling proved 16 out of 20 microbial anomalies. Sokolov *et al.* [4] reported that the correctness of predictions based on geomicrobiological and gas-biological surveys averaged about 70% for a number of regions. Strawinski and Cox [5] used microbial prospecting in Louisiana to correctly predict two producers and two dry holes.

Moody *et al.* [6] surveyed six oil and gas fields in Mississippi, producing from depths of 1,015m to 5,639m, with some being oil producing and others gas producing, some being structural traps and others being stratigraphic traps; all of the fields were successfully located using the Brown [7] geomicrobiological prospecting method. It should be noted that the geomicrobiological analyses were conducted on samples sent to the laboratory without any knowledge by the investigator as to the location from which the samples were taken. A compilation of results of some of the tests conducted using the prospecting method described in Brown [7] is given in Table 1. It should be pointed out that all of these tests were conducted and predictions made prior to the drilling of a well.

By far the most active area of petroleum microbiology is MEOR. For example, by 1990 there had been 133 patents issued in the US, 14 in Canada, four in the USSR, three in the United Kingdom and the Netherlands, and one each in Denmark, France, Germany, and Romania [8]. Normally, MEOR processes involve increasing oil production through the use of microbes to either produce compounds that enhance the recovery of oil or they modify the permeability of the oil-bearing formation. While many of the methods require the injection of microbes into the formation, others take advantage of the indigenous flora [9].

Irrespective of whether a given MEOR process involves the use of indigenous microorganisms or those injected into the oil-bearing formation, the conditions in the reservoir must be such that the microbes can grow. Of particular importance are temperature and salinity. In regard to temperature, Kashefi and Lovley [10] described a thermophile that can grow at 121°C, thus showing the potential for growth as deep as 4,000m. In the case of salinity, ZoBell [11] reported growth at NaCl concentrations of over 300g/l.

The ultimate test of whether or not MEOR can significantly contribute to the recovery of oil is the results obtained in actual field trials. The earliest field trials were conducted in Europe (Czechoslovakia, Hungary, Poland and USSR), and in the US, and the results summarised by Davis in 1967 [12]. Later, Lazar summarised field trials conducted between 1956-1991 [13].

Table 1. Summary of results of geomicrobiological prospecting using the Brown (1962) method.

Blind tests of known areas

No. areas	Type of areas	Prediction	% correct
2	Dry	2 Dry	100
10	Oil field	9 Oil, 1 Dry	90

Predictions of offset wells

No. areas	Type of areas	Prediction	% correct
2	2 Dry	2 Dry	100
15	15 Petroliferous	15 Petroliferous (12 completed)	100

Predictions of wildcat areas

No. areas	Type of areas	Prediction	% correct
23	23 Dry	23 Dry	100
8	8 Petroliferous	6 Petroliferous (3 new field)	75

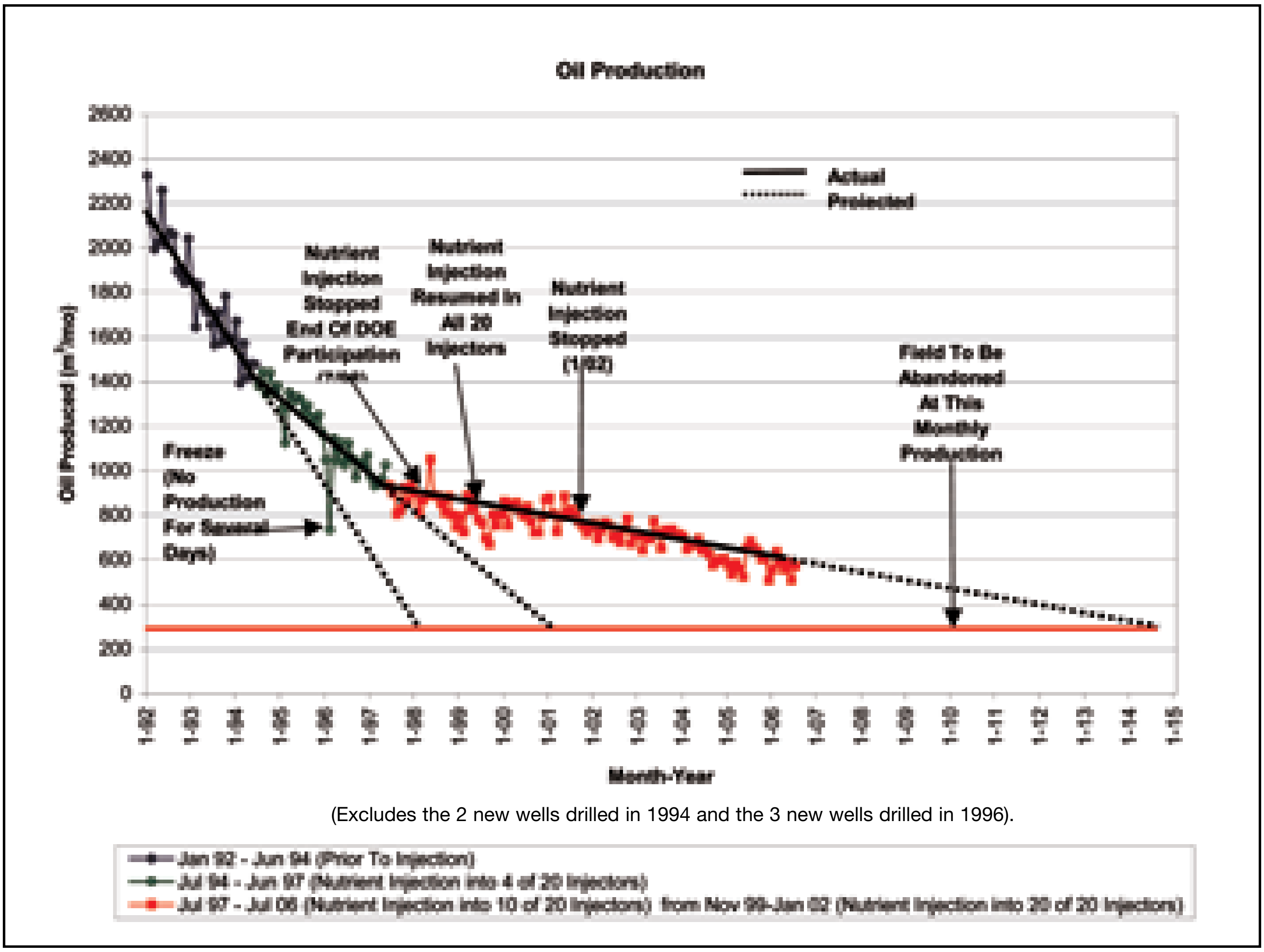

Figure 1. Oil production from the Northblow Horn Creek Unit.

However, as pointed out by Moses, it is not sufficient to simply produce more oil with no understanding of why [14]. A recently completed DOE funded project did explain why the MEOR process employed did increase oil recovery [15]. Figure 1 shows oil production for the North Blowhorn Creek Unit, excluding wells drilled during the course of the project and wells not influenced by the nutrient injections. The field is still producing in 2008 even though it was projected to be abandoned in 1998. Excessive growth of microbes in the reservoir did not occur, since water injection was not significantly reduced even after 9 years. As of today, over 400,000bbl of incremental oil has been recovered from the field even though injection of nutrients was stopped in January of 2002.

In this project, the following results proved that microbes were responsible for the results. Three wells were drilled within the area of the reservoir receiving nutrients; cores from all three wells contained nitrate ions, phosphate ions, and large numbers of microbes as shown in Figure 2 [16]. Gas chromatographic analysis of produced oil proved that oil from new areas of the reservoir was present in the produced oil, clearly indicating that

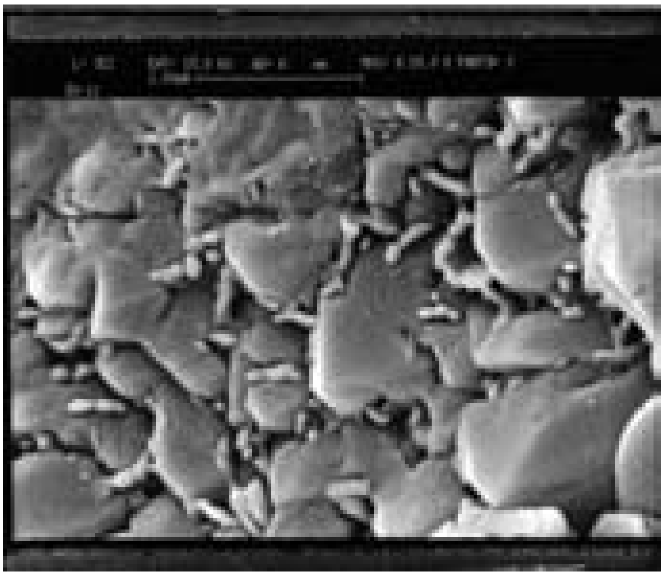

Figure 2. Electron micrograph of a sample of core from a well in an area subjected to injection water containing sodium nitrate and dipotassium hydrogen phosphate. Note the large number of microbial cells.

the sweep profile of the waterflood was being altered by the microbial growth. Also, the produced gas contained a percentage of propane that was typical of gas obtained from the field initially, rather than gas produced from the mature field.

The petroleum industry is being hard pressed to keep pace with the ever-increasing demand for more oil. More and more leaders in the industry are realising that microbes may be able to make meaningful contributions to this effort, not only in the areas of locating new deposits or employing MEOR technology, but in many other areas of the industry. For example, reducing the viscosity of heavy oil makes it more amenable to production and the removal of paraffin from the well bore of producing wells increases production rates. Elimination of hydrogen sulfide from oil reduces many of the corrosion problems faced by the industry. Also, new microbiological techniques, such as genetic engineering, may help to increase the effectiveness of microbes being employed in bioremediation of oil spills.

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