CONSIDERATIONS ABOUT RECENT PREDICTIONS OF IMPENDING SHORTAGES OF PETROLEUM EVALUATED FROM THE PERSPECTIVE OF MODERN PETROLEUM SCIENCE.

J. F. Kenney

Joint Institute of the Physics of the Earth

Russian Academy of Sciences, Moscow;

Gas Resources Corporation, Houston.

ABSTRACT: For almost a century, various predictions have been made that the human race is imminently going to run out of available petroleum. The passing of time has proven all those predictions to have been utterly wrong. It is pointed out here how all such predictions have depended fundamentally upon an archaic hypothesis from the 18th century that petroleum somehow (miraculously) evolves from biological detritus, and is accordingly limited in abundance. That hypothesis has been replaced during the past forty years by the modern Russian-Ukrainian theory of deep, abiotic petroleum origins which has established that petroleum is a primordial material erupted from great depth. Therefore, petroleum abundances are limited by little more than the quantities of its constituents as were incorporated into the Earth at the time of its formation; and its availability depends upon technological development and exploration competence.

"***Rock oil originates as tiny bodies of animals buried in the sediments which, under the influence of increased temperature and pressure acting during an unimaginably long period of time, transform into rock oil*** **[petroleum, or crude oil]"**

Academician Mikhailo V. Lomonosov, "Slovo o reshdenii metallov ot tryaseniya zemli," *Proceedings of the Imperial Academy of Sciences*, St. Petersburg, **1757**.

"***The overwhelming preponderance of geological evidence compels the conclusion that crude oil and natural petroleum gas have no intrinsic connection with biological matter originating near the surface of the Earth. They are primordial materials which have been erupted from great depths***."

Academician Professor Vladimir B. Porfir'yev, senior petroleum exploration geologist for the U.S.S.R., at the *All-Union Conference on Petroleum and Petroleum Geology*, Moscow, **1956**.

"***Statistical thermodynamic analysis has established clearly that hydrocarbon molecules which comprise petroleum require very high pressures for their spontaneous formation, comparable to the pressures required for the same of diamond. In that sense, hydrocarbon molecules are the high-pressure polymorphs of the reduced carbon system as is diamond of elemental carbon. Any notion which might suggest that hydrocarbon molecules spontaneously evolve in the regimes of temperature and pressure characterized by the near-surface of the Earth, which are the regimes of methane creation and hydrocarbon destruction, does not even deserve consideration***."

Professor Emmanuil B. Chekaliuk, at *All-Union Conference on Petroleum and Petroleum Geology*, Moscow, **1968**.

"***The eleven major and one giant oil and gas fields here described have been discovered in a region which had, forty years ago, been condemned as possessing no potential for petroleum production. The exploration for these fields was conducted entirely according to the perspective of the modern Russian-Ukrainian theory of deep, abiotic petroleum origins. The drilling which resulted in these discoveries was extended purposely deep into the crystalline basement rock, and it is in that basement where the greatest part of the reserves exist. These reserves amount to at least 8,200M metric tons of recoverable oil and 100B cubic meters of recoverable gas, and are thereby comparable to those of the North Slope of Alaska. It is conservatively estimated that, when developed, these fields will provide approximately thirty percent of the energy needs of the industrial nation of Ukraine***."

Professor Vladilen A. Krayushkin, Chairman of the Department of Petroleum Exploration, Institute of Geological Sciences, Ukrainian Academy of Sciences, Kiev, and leader of the project for the exploration of the northern flank of the Dnieper-Donets Basin, at the *VII-th International Symposium on the Observation of the Continental Crust Through Drilling*, Santa Fe, New Mexico, **1994**.

The purpose of this article is to present a perspective with which the presently existing data of known petroleum reserves and production ought best to be evaluated. The particular subject of this article is the application to such evaluation of the modern Russian-Ukrainian theory of deep, abiotic petroleum origins, an extensive body of knowledge which has been developed and applied during the last forty years. Thus this article must be understood as one dealing with the *context*

of certain statistical data involving the petroleum industry rather than one concerning with the detailed *content* of any part of that data. The specific data of the quantities of known recoverable petroleum presented by several recent writers will be taken in large part without comment. However, many of the conclusions drawn from such data, particularly such as purport to predict the future of available petroleum reserves and of the petroleum industry itself, will be weighed and rejected from the perspective of modern petroleum science.

Throughout the history of the petroleum industry, there have been written numerous articles or reports predicting an imminent demise of that industry all predicated upon assumptions that the supply of producible crude oil in the world was (supposedly) being rapidly depleted and would soon (therefore) be exhausted. (Campbell 1991; Fuller 1993; Campbell 1994; Campbell 1995) In short, the world was (if such were believed), "running out of oil." Happily, all such predictions have, *without a single exception*, been proven wrong.

Contrarily, the statistics of the international petroleum industry establish that, far from diminishing, the net known recoverable reserves of petroleum have been growing steadily for the past fifty years. Those statistics show that, for every year since about 1946, the international petroleum industry has discovered at least five new tons of recoverable oil for every three which have been consumed. As Professor P. Odell has put the circumstance succinctly, instead of "running out of oil," the human race by every measure seems to be "running *into* oil".(Odell 1984; Odell 1991; Odell 1994)

The remarkable facts of such unrelieved errors for the predictions of available petroleum contrasted against those of its true availability demand explanation. One purpose of this paper is to provide such explanation. The explanation involves two parts, both of which obtain from an extensive body of scientific knowledge which peculiarly remains little known outside its country of origin. The first part of the explanation is simply forthcoming by pointing out the single, simple, but utterly wrong assumption upon which have been based all the "disaster" predictions connected with fantasized shortages of petroleum. The second part consists even more simply of pointing out how the measured statistics of known petroleum reserves are consistent with what should be expected in light of modern petroleum science.

The errors concerning the abundances of petroleum on Earth all obtain from a common, but fundamental, misunderstanding about petroleum itself. All the predictions about expected shortages of petroleum hang by a single, weak thread on a remnant, eighteenth-century notion which has been thoroughly discredited in this century: the hypothesis that petroleum might somehow originate from biological detritus in sediments near the surface of the Earth. That "biological hypothesis" was first published by the famous Russian scientist Mikhailo Vasilyevich Lomonosov in the year 1757 and is quoted above. That notion of an origin of petroleum from biological material has occasioned numerous misnomers concerning petroleum as, for example, "fossil" fuel, and associated, misleading phrases like "vanishing resource." Because the volume of biological matter on Earth is itself limited, the misunderstanding that petroleum might originate from such has given rise consequentially to a notion that petroleum should be similarly limited, and somehow in connection with the quantity of biogenic material observed in sediments.

The hypothesis that petroleum might somehow originate from biological detritus in sediments near the surface of the Earth is utterly wrong. It deserves note that Lomonosov himself never meant for that hypothesis to be taken as more than a reasonable suggestion, to be tested against further observation and laboratory experiment. The "biological hypothesis" of petroleum origins has been rejected in this century by scientific petroleum geologists because it is formidably inconsistent with the existing geological records "on the ground." That hypothesis has been rejected also by physicists, chemists, and engineers because it violates fundamental physical law.

Lomonosov's eighteenth-century hypothesis of a biogenic origin of petroleum has been replaced during the past forty years by the modern theory of deep, abiotic petroleum origins, an extensive and formidable body of scientific knowledge which has been developed in the former U.S.S.R., particularly in the countries Russia and Ukraine. The modern Russian-Ukrainian theory of petroleum has established that petroleum is a primordial material of deep origin which has been erupted into the crust of the Earth.

With the elimination of the error that petroleum might be some manifestation of transformed, but limited, biological matter originating on the surface of the Earth, the consequential errors connected with its supposed limits both of quantity and habitat vanish. Thus the errors of all the "doomsday" predictions of petroleum shortages, which have never subsequently occurred, are explained, - or, more simply, eliminated.

Because the explanation of the errors connected with the predictions about petroleum shortages obtains simply from the modern Russian-Ukrainian theory of deep, abiotic petroleum origins, and because that theory is little known outside the former U.S.S.R., its subject deserves at least short mention.

The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is an extensive body of scientific knowledge covering the subjects of the chemical genesis of hydrocarbon molecules, the physical processes which occasion their terrestrial concentration, the dynamical processes of the movement of that material into geological reservoirs of petroleum, and the location and economic production of petroleum. As stated, the modern theory has determined that petroleum is a primordial material of deep origin which is transported at high pressure via "cold" eruptive processes into the crust of the Earth. The modern Russian-Ukrainian theory is almost unique among what too often pass as "theories" in the field of geology (especially in the U.S.A.) in that it is based not only upon extensive geological observation but also upon rigorous, analytical, physical reasoning. Much of the modern Russian theory of deep, abiotic petroleum genesis developed from the sciences of chemistry and thermodynamics, and accordingly the modern theory has steadfastly held as a central tenet that the generation of hydrocarbons must conform to the general laws of chemical thermodynamics, - as must likewise all matter. With the exception of methane, the alkane of the lowest chemical potential of all hydrocarbons, and to a lesser extent ethene, the alkene of the lowest chemical potential of its homologous molecular series, petroleum has no intrinsic association with biological material. Methane is thermodynamically stable in the pressure and temperature regime of the near-surface crust of the Earth and accordingly can be generated there spontaneously, as is indeed observed for such phenomena as swamp gas or sewer gas. However, methane is practically the sole hydrocarbon molecule possessing such characteristic in that thermodynamic regime; almost all other reduced hydrocarbon molecules excepting only the lightest ones, are high pressure polymorphs of the hydrogen-carbon system. The genesis of heavier hydrocarbons occurs only in multi-kilobar regimes of high pressures†.

The modern Russian theory of deep, abiotic petroleum origins is no longer an item of academic debate among persons in university faculties in the former Soviet Union. This body of knowledge is now approximately a half century old and has moved considerably beyond the stages of academic research and scientific testing. Today the modern theory is applied as a useful tool and the guiding perspective in petroleum exploration throughout the former Soviet Union. Such was exactly one of the primary points brought out in a paper delivered at an international conference held in Santa Fe, New Mexico, in May 1994, concerning the discovery of the eleven major and one giant oil and gas fields in the Dnieper-Donets Basin.(Krayushkin, Tchebanenko et al. 1994)

Because of the general lack of familiarity outside the former U.S.S.R. with the modern Russian-Ukrainian theory of deep, abiotic petroleum origins, several immediate facts about that body of knowledge deserve to be set forth.

- **The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is *not* new or recent**. This theory was first enunciated by Professor Nikolai Kudryavtsev in 1951, almost a half century ago,(Kudryavtsev 1951) and has undergone extensive development, refinement, and application since its introduction. There have been more than four thousand articles published in the Soviet scientific journals, and many books, dealing with the modern theory. This writer is presently co-authoring a book upon the subject of the development and applications of the modern theory of petroleum for which the bibliography requires more than thirty pages.

- **The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is *not* the work of any one single man, - nor of a few men**. The modern theory was developed by hundreds of scientists in the (now former) U.S.S.R., including many of the finest geologists, geochemists, geophysicists, and thermodynamicists of that country. There have now been more than two generations of geologists, geophysicists, chemists, and other scientists in the U.S.S.R. who have worked upon and contributed to the development of the modern theory.(Kropotkin 1956; Anisimov, Vasilyev et al. 1959; Kudryavtsev 1959; Porfir'yev 1959; Kudryavtsev 1963; Raznitsyn 1963; Krayushkin 1965; Markevich 1966; Dolenko 1968; Dolenko 1971; Linetskii 1974; Letnikov, Karpov et al. 1977; Porfir'yev and Klochko 1981; Krayushkin 1984)[f]

- **The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is *not* untested or speculative**. On the contrary, the modern theory was severely challenged by many traditionally-minded geologists at the time of its introduction; and during the first decade thenafter, the modern theory was thoroughly examined, extensively reviewed, powerfully debated, and rigorously tested. Every year following 1951, there were important scientific conferences organized in the U.S.S.R. to debate and evaluate the modern theory, its development, and its predictions. The All-Union conferences in petroleum and petroleum geology in the years 1952-1964/5 dealt particularly with this subject. (During the period when the modern theory was being subjected to extensive critical challenge and testing, a number of the men pointed out that there had never been any similar critical review or testing of the traditional hypothesis that petroleum might somehow have evolved spontaneously from biological detritus.)

- **The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is *not* a vague, qualitative hypothesis, but stands as a rigorous analytic theory within the mainstream of the modern physical sciences**. In this respect, the modern theory differs fundamentally not only from the previous hypothesis of a biological origin of petroleum but also from all traditional geological hypotheses. Since the nineteenth century, knowledgeable physicists, chemists, thermodynamicists, and chemical engineers have regarded with grave reservations (if not outright disdain) the suggestion that highly reduced hydrocarbon molecules of high free enthalpy (the constituents of crude oil) might somehow evolve spontaneously from highly oxidized biogenic molecules of low free enthalpy. Beginning in 1964, Soviet scientists carried out extensive theoretical statistical thermodynamic analysis which established explicitly that the hypothesis of evolution of hydrocarbon molecules (except methane) from biogenic ones in the temperature and pressure regime of the Earth's near-surface crust was glaringly in violation of the second law of thermodynamics. They also determined that the evolution of reduced hydrocarbon molecules requires pressures of magnitudes encountered at depths equal to such of the mantle of the Earth. During the second phase of its development, the modern theory of petroleum was entirely recast from a qualitative argument based upon a synthesis of many qualitative facts into a quantitative argument based upon the analytical arguments of quantum statistical mechanics and thermodynamic stability theory. (Chekaliuk 1967; Boiko 1968; Chekaliuk 1971; Chekaliuk and Kenney 1991; Kenney 1995) With the transformation of the modern theory from a synthetic geology theory arguing by persuasion into an analytical physical theory arguing by compulsion, petroleum geology entered the mainstream of modern science.

- **The modern Russian-Ukrainian theory of deep, abiotic petroleum origins is *not* controversial nor presently a matter of academic debate**. The period of debate about this extensive body of knowledge has been over for approximately two decades(Simakov 1986). The modern theory is presently applied extensively throughout the former U.S.S.R. as the guiding perspective for petroleum exploration and development projects. There are presently more than 80 oil and gas fields in the Caspian district alone which were explored and developed by applying the perspective of the modern theory and which produce from the crystalline basement rock.(Krayushkin, Chebanenko et al. 1994) Similarly, such exploration in the western Siberia cratonic-rift sedimentary basin has developed 90 petroleum fields of which 80 produce either partly or entirely from the crystalline basement. The exploration and discoveries of the 11 major and 1 giant fields on the northern flank of the Dneiper-Donets basin have already been noted. There are presently deep drilling exploration projects under way in Azerbaijan, Tatarstan, and Asian Siberia directed to testing potential oil and gas reservoirs in the crystalline basement.

The errors involved in predictions about the future availability of petroleum, inevitably occasioned by an inappropriate application of the rococo hypothesis that petroleum somehow miraculously evolved from limited volumes of biogenic matter, obtain generally from the very notion of such as a "limited, fossil" material. Correctly, one should better recognize that there exists no more reason to expect a future shortage of petroleum than of, say, mid-oceanic ridge basalt (MORB). [MORB is the rock characteristic of the loci of the deep suture, spreading zones on the mid-ocean floor where new oceanic crust is constantly being erupted from the mantle of the Earth.] Those predictive errors obtain specifically from neglect of several extremely large potential sources of petroleum, of which a few are set forth here.

(1.) The potential to produce petroleum from the crystalline basement, from volcanic structures, from impact structures, and from non-sedimentary regions generally has been entirely neglected.

(2.) The petroleum potential of the riftogenic suture zones, both subsea and on-shore, have been largely neglected.

(3.) The petroleum which certainly exists and will surely be produced from reservoirs underneath those presently being produced has been almost entirely neglected[‡].

(4.) The potential to produce petroleum gas from reservoirs beneath the methane clathrate zones has been completely neglected, as has mostly the same of the methane clathrate reserves themselves.

(5.) The potential that certain of the petroleum fields presently producing may be drawing pressured hydrocarbons from an open and active fault or conduit from the mantle, and therefore, may never be depleted,[§] has been entirely neglected, as has the potential to develop non-depleting fields by deep drilling. (Mahfoud and Beck 1995)

In view of these considerations, there stands no reason to worry about, and even less to plan for, any predicted demise of the petroleum industry based upon a vanishing of petroleum reserves. On the contrary, these considerations compel additional investment and development in the technology and skills of deep drilling, of deep seismic measurement and interpretation, of the reservoir properties of crystalline rock, and of the associated completion and production practices which should be applied in such non-traditional reservoirs.

Not only are any predictions that the world is "running out of oil" invalid, so also are suggestions that the petroleum exploration and production industry is a "mature" or "declining" one. This writer's experience, gained from working in the former U.S.S.R. during the past five years, has provided compelling evidence that the petroleum industry is only now entering its adolescence.

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† Just as diamonds can be created in a laboratory at low pressures by such processes as an acetylene plasma, so likewise can heavy hydrocarbons be synthesized by such as the Fischer-Tropsch process. But neither process is much mimicked in natural circumstances, and under such thermodynamic conditions of synthesis, the produced hydrocarbons are unstable and would decompose in any natural environment.

f In the very abbreviated bibliography are given only a selection of the earliest works published in the subjects by those particular men. For examples, both Krayushkin and Porfir'yev published each more than two hundred articles and several monographs on the subject.

‡ And such neglect occurs now forty-five years *after* Kudryavtsev taught the petroleum industry about those reservoirs !

§ It deserves to be pointed out that such neglect continues despite these possibilities having been brought to the attention of the international petroleum industry in western trade journals.(Mahfoud and Beck 1995)

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