The non-organic theory of the genesis of petroleum

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Recent advances in interdisciplinary fields as diverse as astrophysics, cosmogeophysics, nuclear geology, etc. have led to interesting developments in the non-organic theory of the genesis of petroleum. This theory, which holds that petroleum is of an abiogenic primordial origin, provides an explanation for certain features of petroleum geology that are hard to explain within the standard organic framework. If the non-organic theory is correct, then hydrocarbon reserves would be enormous and almost inexhaustible.

PETROLEUM is the foundation of the industrial civilization. It is from petroleum that the world obtains its chemicals, fuel for automobiles, engines, airplanes, etc. and its energy supply for its power stations. Empires have risen and fallen due to the annexation or loss of oil fields. Hence, the origin of petroleum and the assurance of future energy supplies is of the utmost importance if this world is to continue as it is. It is generally believed that currently recoverable crude oil reserves will be nearing exhaustion within a few decades. This estimate is based on the conventionally accepted (organic) theory of the origin of petroleum.

However it does not necessarily follow that this civilization will fall into darkness. The origin of petroleum still, despite the immense amount of research devoted to it, has more uncertainties concerning it than any other common natural substance[1].

There are two basic frameworks: the standard organic theory, and the non-organic theory. The former holds that petroleum is of an organic origin and is the currently favoured proposal. It predicts limited reserves worldwide; moreover Indian reserves are predicted as minimal. The latter maintains that it is of non-organic genesis, supposedly of primordial origin. On the basis of this theory, oil resources would be much larger than those predicted by the biogenic theory. India, oil-poor in the biogenic framework, is predicted to be oil-rich in the non-organic one.

Unfortunately the abiogenic theory and its implications are not well known. Moreover, both opposing sides have taken uncompromising, even fundamentalist views on occasions. There is hence a crucial need, especially for nations such as India, to objectively assess the situation and investigate the latter possibility more carefully; especially since, as we shall discuss below, the evidence in favour of either candidate is inconclusive and the question still remains an open one.

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The organic theory

Outline

The organic theory holds that the first stage of the genesis of petroleum involves plankton (single-celled organisms that float on the oceans). These die and gradually accumulate on the ocean floor. Other sediments start accumulating too, and after a few million years the plankton are buried under several km of sediment. The plankton, which have remained unoxidized, under the increased values of pressure and temperature, are now transformed into kerogen. Under favourable conditions of time and temperature this kerogen, after further burial and heating, is transformed, via cracking, into petroleum and natural gas. These then migrate towards the surface and end up either reaching it (and drying up to yield bitumen or tar) or being arrested on the way in traps (where, millions of years later, drillers of the present industrial age make their big strikes)[2].

Advantages

Traditionally, the following points have been considered as supporting the biological theory:

(i) Since it is known that hydrocarbons can be produced by photosynthesis, it is natural to expect petroleum to be of an organic origin.
(ii) Molecules thought to be of biological origin, e.g. porphyrins, isoprenoids, hopanoids, etc. were found in petroleum, thereby providing support for the organic theory.
(iii) The organic carbon in plants is depleted in carbon-13 due to the process of photosynthesis. In dead organic

material the C-13 is further depleted due to radioactive decay. Since it was found that most petroleum and natural gas showed the same depletion, it was viewed as a strong proof in favour of an organic origin.
(iv) Sediments are the most important host rocks yielding petroleum, i.e. the oil produced from oil wells is generally obtained from a porous sandstone deep below. Often sediments are associated with biological material that could have acted as a source of the petroleum.
(v) The existence of large quantities of oil shale from which a hydrocarbon mix similar to petroleum could be distilled was seen as a support in favour of an organic origin. This followed easily, since the oil shale was taken to be the kerogen source rock which, on sufficient burial, purportedly yielded petroleum.

Disadvantages

However the following observations go against the organic theory:

(i) The discovery that meteorites contain hydrocarbons came as a great blow to advantages no. (i) and (ii) of the organic theory. Porphyrins and isoprenoids have been found on meteorites[3]. In addition, the outer planets contain large amounts of hydrocarbon.
(ii) The concentration of oil in the Middle East implies that that region must have been exceptionally prolific in plant and animal life over long periods of the Earth's history. This is unlikely, since life tends to be more dispersed, even today.
(iii) The biological supports of optical activity and an odd-even effect disappear at low levels. There is a sharp cutoff to the effect of optical activity: petroleum in Philippi's study[4] was found to be optically active if derived from a reservoir with a temperature below 66°C, but surprisingly petroleum from deeper levels of the same field did not exhibit the phenomenon of optical activity. Gold[5] proposed that a certain bacteria ceases action above 66°C, but he unfortunately did not suggest any candidates.
(iv) Methane occurs in giant ocean rifts, in continental rifts and the lakes that occur nearby, e.g. dissolved in the waters of the East African Lake Kivu[6], as methane hydrates in permafrost, in active volcanic and mud volcanic regions, as well as at great depths of more than 10 km as geopressured gas etc. A biological origin for this methane can be virtually ruled out.

In the light of these difficulties one should consider the other rival non-organic theories as serious possibilities. They forecast much larger oil reserves than previously imagined and that too in regions which, according to the organic theory should be devoid of all petroleum.

The non-organic theory

Historical development

The non-organic theory of the genesis of petroleum has a long history, dating back to the early days of the oil industry. Its development has led to the birth of a number of variants, the most important of which are outlined below:

Metal carbide theory. The founder of the non-organic theory was Mendeleev, the Russian chemist who proposed the modern version of the periodic table. In 1877, he wrote that the petroleum deposits of the world seem to be controlled more by large scale tectonic features than by the ages of sedimentary rocks[7]. To explain these observations he put forth the metal carbide theory. Many contemporary investigators, mostly Russian, supported Mendeleev's view.

In this model metal carbides deep within the earth reacted with water at high temperatures to form acetylene which subsequently condensed to form heavier hydrocarbons (as is readily formed in the lab). The following reaction

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$$

is still popular amongst some astronomers and certain Russian geologists as a major petroleum-forming possibility[2].

Nebular condensation theory. In 1980 Sokoloff proposed that 'bitumina', at that time meaning the whole range of hydrocarbons from petroleum to tar, precipitated as rain onto the newly forming earth from the original nebular matter from which the Solar System was formed. In modern terminology he simply suggested that petroleum originated from meteorites. Later, he claimed, this petroleum was ejected from the earth's interior into the surface sediments[8]. Recently this idea has been supported by Hoyle, who proposes that not only oil, but life itself has extra-terrestrial origins[9].

Volcanic origin theory. This postulate involves outgassing of the mantle via volcanic activity[10].

Earthquake outgassing. This theory proposes that outgassing occurs via deep faults, and that this is still occurring today. The detailed mechanism has a long history. Vernadsky propounded the notion that hydrocarbon compounds would be stable against dissociation and oxidation at great depths and would replace carbon dioxide as the chief carbon-bearing fluid. Kudryavtsev set forth the observations supporting what was later to be known as Kudryavtsev's rule (to be discussed shortly).

Gold[5,11] has become the main proponent of the idea of a non-organic origin in the West. Due to his initiative, a hole was drilled into crystalline basement rock which Gold predicted should yield petroleum. Only noncommercial quantities of petroleum, if any, were found. Moreover most of Gold's colleagues were not convinced. However, recently a nearby hole did strike oil (see below). This is now the most commonly known variant.

However, since Western nations either possess or control much of the world's petroleum reserves, there is no incentive to innovate. Since the nonorganic theory predicts petroleum in much larger quantities and in areas hitherto considered unfavourable, it is petroleum-poor countries like India who stand most to gain. Hence, it is they who should take the risks of exploring the non-organic theory, both theoretically and experimentally.

These are the prime variants of the theory. From now on, the word 'non-organic theory' shall be taken to propound merely a primordial (i.e. dating from the birth of the Earth) origin of petroleum which has been migrating outwards from great depths of the Earth to form all hydrocarbon deposits from tar and tar sands to oil shale. The detailed mechanisms mentioned above shall not complicate the issue during the course of the following discussion.

Outline of the theory

The theory suggests that most of the hydrocarbons on earth are in fact primordial. Carbonaceous chondrites appear to have been the most abundant source rock during the formation of the earth. This type of meteorite contains a significant amount of hydrocarbons. As the earth formed, it would have acquired these hydrocarbons via accretion (bodies of roughly equal size clumping together through collisions), and later through meteorite impacts (including hydrocarbons formed by the reaction of meteoritic carbon with H_2 at high pressures and temperatures on impact). Then as the earth gradually cooled, a solid crust developed, while the interior remained liquid or semisolid. The volatile substances would be expelled from the interior. It is such gases that yielded, after biological modification, the present atmosphere. That hydrocarbons are being evolved from the inner parts of the earth is evident from the presence of mud volcanoes, flames seen during earthquakes, etc. On the way up, it is supposed, the oil (dissolved in methane) would be trapped in suitable formations creating the world's oil and gas, tar sands, oil shales, bitumen, mud volcanoes, etc.[11] Kropotkin and Valyaev[12] pointed out that the hydrocarbons, carried upwards by streams of compressed gases, would have two possible destinies: (i) In volcanic regions, they would be oxidised to carbon dioxide and water, and (ii) In 'cool' regions the hydrocarbons would form oil and gas reservoirs after condensation from the rising stream at levels possessing the requisite values of temperature and pressure.

Evidence in favour of the non-organic theory

Geographical location. The major oil fields of the world are concentrated on or near belts of major tectonic activity or in fact along fault zones. Some of the phenomenal Arabian fields, the world's largest petroleum province, lie along the Persian Zagros Mt. belt. The large North Sea reserves that have made much of Northern Europe self-sufficient in oil production lie along the North Sea trench. The oil fields of Indonesia and Burma closely follow the seismic belt running from New Guinea to Burma, while the oil fields of Gujarat appear to be associated with the Cambay fault. Hydrocarbons are found in the Red Sea rift Valley, the East African rift and the eastern branch of the Pacific rift. These and many other examples that exist should illustrate the association of hydrocarbons with large deep-seated cracks in the Earth's crust rather than any local sediments. However, note the idea of deep-seated cracks may also be required to explain the migration of petroleum within the organic theory.

According to the non-organic theory, petroleum should occur universally in areas of tectonic activity. This does not appear to hold true, and this seems to be a problem for the non-organic theory.

Multilevel fields. It is observed that petroleum, in at least small quantities, is often present in horizons below many accumulations, largely independent of the composition and mode of formation of the horizon. This is known as Kudryavtsev's rule, and several examples of it have been noted[13]. The suggestion that the petroleum seeps from underneath is supported by the evidence of fractionation, although this can also be explained by migration from deep source rocks within the organic framework as well.

Methane-bearing strata in the same column show a progressive depletion in the isotope carbon-13 as one rises from lower levels to higher levels[14]. The organic theory holds that petroleum originating from source rocks buried several km within the earth explains these properties. The oil and gas formed would migrate upwards, thereby explaining both fractionation and Kudryavtsev's rule. However, this effect would be a natural consequence of the upward migration of primordial gases, with the heavier isotopes of carbon rising more slowly than the lighter one.

Stability with depth. It was once thought that petroleum and natural gas would not be able to survive at depths greater than a few tens of kilometres below the surface as the temperatures occurring there exceeded those observed to destroy petroleum and natural gas in labs. Hence, it was reasoned, it was pointless to look for either the fuel or its origin in the depths of the Earth. However that picture has changed radically. Huge quantities of gas have been discovered at great depths, e.g. in the Anadarko basin in Oklahoma. Reservoirs of 'geopressured gas' have been found to underlie all major oil-bearing regions. These are sandstones and shales containing enormous amounts of gas dissolved in salt brines. Reserves of such gas are estimated at 60000 TCF (trillion cubic feet) in the US alone[15], exceeding by several factors the total conventional gas reserves of the world.

In addition, vast domains of gas exist in open fractures of non-sedimentary basement rock. A deep hole currently being drilled in Germany has found these at depths of up to 4 km[16]. Theory had to be revised, and Chekaliuk[17] showed that not only could natural gas exist at extreme depths but petroleum could, too. The earlier experiments had simply not been done at the correct pressures. In fact, the pressures encountered stabilize oil and natural gas against dissociation despite extreme temperatures, so that methane could exist up to 30 km with only 5% dissociated. Further, thermodynamic calculations show that petroleum itself is mostly stable between 30 and 300 km. Although this is heartening from the perspective of the non-organic theory, this does not necessarily go against the organic theory, as we discussed earlier.

Sugisaki and Nagamine[18] have recently investigated the thermodynamic equilibrium of light hydrocarbon gases. Thermodynamic equilibrium of a gas is revealed by the concentrations of its constituents. They studied the reaction

$$CH_4 + C_3H_8 = 2C_2H_6.$$

At equilibrium the graph of $[CH_4] \times [C_3H_8]$ vs $[C_2H_6]$ is a graph of constant slope. Moreover, the temperature of equilibrium can be calculated from this graph. It was found that hydrocarbon gases released by crushing plutonic rock and natural gas from deep wells displayed these features, indicating chemical equilibrium. On the other hand, gases issuing from a peat bog, shallow gas wells, and, significantly, pyrolysis products from kerogen, coal and other organic substances did not, although the temperature was 350°C (thus exceeding the equilibrium temperature of 180°C for the plutonic gases) and the longest experimental period was 555 days. Quite naturally this is a puzzle, since if kerogen were the source of petroleum, then the hydrocarbons released through pyrolysis of kerogen should display the chemical equilibrium shown by the deep-level hydrocarbons. It should be noted that this work[18] pertains to thermodynamic equilibrium of light hydrocarbon gases and not to the stability of the same.

The team explained these observations in terms of the organic theory as follows: After the decomposition of petroleum, kerogen and other heavy hydrocarbons, the gases attain chemical equilibrium at the high temperatures existing at great depths. As the gas cools, either by upward migration or by cooling of the volcanic rock (in the case of the plutons), the gas composition is frozen in once the temperature becomes so low that the gas composition effectively freezes in. To explain the negative result, i.e. the lack of equilibrium of the pyrolysis products, they are forced to make the rather unilluminating assumption that the rate of reaction was so slow that equilibrium could not be attained even after $1\frac{1}{2}$ years.

A far more natural explanation, which the authors cited above chose not to investigate, is using the non-organic theory. If it is assumed that the hydrocarbons are primordial and originate from the depths of the earth, then they would naturally display the signatures of chemical equilibrium as it would have been subject to high temperatures for a much longer time. As the hydrocarbons migrate upwards, they would, at shallow levels, be invaded by bacteria, thereby losing the signatures of equilibrium.

Critics suggest that oxidation would destroy any petroleum anyway turning the hydrocarbons into CO_2, H_2O and coke, the constituents of volcanic gases. Since these come from deep inside the Earth, the primordial hydrocarbons, even if they existed, would have been destroyed. However that is not the full story. Substantial evidence indicates that unoxidised carbon exists at great depths. Unoxidised carbon can also exist at great depths within the organic framework, coke being produced by the decomposition of hydrocarbons.

Existence of unoxidised carbon at great depths

The following evidence suggests that large masses of unoxidised carbon exist at great depths:

Diamonds. These provide evidence of the existence of carbon at great depths in unoxidised form, i.e. other than CO_2, since diamond is pure carbon.

The diamonds might have been associated with extremely violent explosions, since if the diamonds had risen slowly along with magma of the type spewed out by conventional volcanoes (e.g. Hawaii), they would have been transformed into graphite. As thermodynamical calculations and experience in the production of artificial diamonds show, diamonds must be cooled quickly to exist. Moreover the associated host rock contains other high pressure minerals like peridotite (believed to be one of the principal constituents of the mantle), etc. The primary deposits of diamonds are the rare kimberlite pipes, named after the now legendary South African town of Kimberley which was once the chief source of these stones. These are deep vertical shafts, funnel-like near the surface and gradually narrowing with depth, presumably becoming a fissure extending all the way to the upper mantle where the pressure and temperature are suitable for the formation of diamonds (45 kbars and 1000°C approx.). Why are they so deep? How were they formed? Moreover, if they are volcanic in origin, as they appear to be, why is no lava associated with them? The only plausible conclusion is that the pipes were caused by extremely violent eruptions of gas that blasted a hole through 150 km of overlying dense rock. The observation, that the pore spaces of natural diamonds contain highly compressed gases including CO_2 and CH_4 (ref. 19) and the result that heavy hydrocarbons clearly distinguishable from the surrounding rocks exist in the East Siberian pipes[20], including the observation that bore holes into these pipes yield significant quantities of CH_4 (ref. 21) enforce the following conclusions:

(i) Unoxidised carbon exists in the outer mantle in the form of methane and hydrocarbons, as does pure carbon.
(ii) Volatile-rich regions exist in the inhomogeneous mantle which have been giving off hydrocarbon gases long after the formation of the earth's crust which can build up such great pressures that they simply crack through the crust in violent explosions.

Earthquakes. The eruptions of gas mentioned above, the generation of which is not disputed by the organic theory, should cause earthquakes. In fact, earthquakes have been observed to be associated with gas ejection throughout recorded history.

Greco–Roman civilization. Anaxagoras first proposed the theory that gases ('air') were the cause of earthquakes[5 (p. 49)]. Seneca, Pliny, Pausanias and Aelian mention the evolution of 'wind', strange animal behaviour, great flames rising from the ground, loud roaring noises, foul smell and peculiar fog and the development of peculiar odour and muddy appearance in the water of wells and springs occurring several days or months prior to the earthquake.

Anglo-Saxon age. Newton wrote that he felt 'sulphurous fumes' were the cause of earthquakes[5 (p. 51)]. Mitchell reasoned that gases caused the slow, visible oceanlike waves that roll across landscapes during major earthquakes. He also points out that the sudden deaths of large numbers of fish would be most naturally explained by the evolution of poisonous gases from vents in the ocean floor. Alexander von Humboldt summarized the then accepted theory as 'elastic fluids seeking an outlet to diffuse themselves into the atmosphere' being the cause of earthquakes. Thousands of fish, many of a nature previously unknown to local fishermen, were found floating on the water in Monterrey Bay on the day of the destructive San Francisco earthquake of 18 April 1906 (ref. 5, p. 63). Similar reports come from Japan. Hydrogen sulphide, highly toxic to fish, is a likely candidate, killing the bottom dwelling fish that are not normally caught.

Chinese civilization. More recently, at the Sungpan-Pingwu earthquake (Aug. 1976), outbursts of natural gas from rock fissures were reported. Moreover, these sometimes ignited, creating fireballs. A total of 1000 were sighted. A few hours before the earthquake, the water in local wells was observed to exhibit a violent bubbling[5 (p. 61,62)].

These reports spanning recorded history show that methane gas is closely associated with earthquakes. In fact it is not unreasonable to suggest that earthquakes are caused by enormous build-ups of highly compressed gases containing mostly methane. This is in fact a strong support in favour of the non-organic theory, since the amounts of methane evolved are too large to have been produced by biological sources.

Mud volcanoes. These instead of ejecting lava and gas like ordinary lava volcanoes, emit mud and gas instead. The cones built up by them, consisting of solidified mud, are similar to, but smaller than, those built by the lava volcanoes. They emit mostly methane, while smaller amounts of other hydrocarbons are also present, including other inorganic gases like He, H_2, CO_2 or steam. Many mud volcanoes simply eject high pressured unconsolidated mud. In contrast, lava volcanoes emit mostly carbon dioxide and water. Mud volcanoes closely follow the underlying fault lines. This is not just commonplace, but holds for all mud volcano regions of the world. Moreover, the quantities of gas required to produce the Soviet mud volcano fields have been estimated to be several times the total gas content of the largest known gas field[5 (p. 101)]. How does one explain this?

The conventional explanation in terms of the organic framework is that the gas is generated by bacterial action on the organic content of the mud. However, this has some problems:

(i) The gas so generated would bubble up on a continuous basis, and hence extremely violent explosions of the type observed in the major mud volcano regions of the world would be extremely unlikely, as large concentrations of gas most probably not build up.
(ii) Chemical analysis reveals that the methane also contains significant amounts of methane, propane and other hydrocarbons. Moreover, mercury, helium and other trace elements occur in the gases. The carbon isotope ratio is sometimes quite different from that expected to be obtained from a biologically derived material.

The inorganic explanation is that the gradually upward migrating gaseous hydrocarbons build up beneath impervious rocks, and then after having built up sufficient pressure, smash through the overlying rock, creating violent explosions of the type observed. These violent displacements of gas will cause violent turbulence of the water, which would stir up the fine-grained sediment, creating the mud so characteristic of these volcanoes.

Pockmark-like craters on the ocean floor. Crater-like markings on the ocean floor have been reported from the Adriatic, the North Sea, the Gulf of Mexico, the Orinoco Delta, the South China Sea, the Baltic, the Aegean, near New Zealand, and off Nova Scotia[22]. Sonar experiments in the North Sea reveal shallow, circular ridges ranging from a few metres to 200 metres in diameter over an area of 20,000 square kilometres, roughly coinciding with the oil and gas producing region. It appears that individual events were responsible for creating large fields of these 'pockmarks', since one set of pockmarks occurs 10 m below an overburden of more recent sediment, while the other is visible on the surface. Hence it is estimated that while one such event occurred within the last thousand years, another occurred 10,000 years ago. Since small trickles of gas produce small steep-sided cones of mud (as in the Gulf of Mexico, where bubbles issue from the top of these miniature volcanoes), sudden releases of gas must be responsible for the craters. Primordial gas is a good candidate to explain the pockmarks.

The author also points out a remarkable coincidence between the major mud volcano regions of the world and the major oil-producing areas: (i) The Persian Gulf, (ii) the Caspian, (iii) Indonesia and (iv) Venezuela.

The South Alaskan mud volcanoes emit mostly carbon dioxide and are situated near lava volcanoes. Only three mud volcano regions are not correlated with any oil-producing regions: S. Italy, New Zealand, Black Sea. This connection arises naturally in the non-organic approach, since mud volcanoes indicate cool regions of hydrocarbon migration.

Extra-terrestrial hydrocarbons

Meteorites. If primordial hydrocarbons were incorporated in the earth during the process of formation, then one should expect to find such substances in ancient material dating from the formation of the solar system. Such material exists in the form of carbonaceous chondrites, a class of meteorites. Moreover, this type of meteorite seems to be very common. In fact, asteroids and interplanetary material seem to be of largely carbonaceous derivation[23].

Materials previously thought to be exclusively biological in origin have now been found on meteorites. Porphyrin-type molecules are found in meteorites and are almost certainly not of a biological derivation[3].

Planets. The outer planets have their atmospheres largely in the form of hydrocarbons, chiefly methane. Uranus' atmosphere may contain as much as 14% of methane gas[24 (p. 221)]. Neptune's atmosphere consists of hydrogen, helium and methane while the inner liquid shell is thought to consist of water, methane and ammonia[24 (p. 233)].

Comets. Halley's comet (1986) was found to emit hydrocarbon gases. The core was observed to be black, presumably because of it being composed of carbonaceous material. Lang and Whitney describe the interior as blacker than coal, its blackness perhaps being due to 'an admixture of minerals, organic compounds and metals'[24 (p. 254)].

Isotope and trace element anomalies. The following peculiarities point to an extensive upward migration of deep fluids. Moreover, mantle-derived material occurs in association with petroleum:

Helium. This is closely associated with petroliferous regions. In fact the world obtains its commercial supply of helium by separation from natural gas[11 (p. 69)].

Argon-40. Argon and its isotope Ar-40 occur in extraordinarily high concentrations in gas fields[11 (p. 70)]. Moreover, assuming the source of the 0.1% Ar by volume in the huge Panhandle gas field to be the source rock itself implies that the source rock must have been 100% potassium to supply the required levels of Ar-40 (ref. 25). Moreover, high values of Ar-40/Ar-36 are taken as an indication of mantle-derived material[26 (p. 417)]; strikingly petroleum displays this signature.

Experimental verification

The final proof would involve an actual experimental verification of the theory. Deep wells are good tests, since organic materials cannot occur in crystalline basement rocks. Several are under way:

The Kola superdeep hole. At 12 km, this is the world's deepest well (1984). Located in the Kola peninsula, now Russia, it reached deep down into the crystalline basement. The drilling released flows of gas at all levels. The liberated gases included[27] helium, hydrogen, nitrogen, methane and other hydrocarbons and CO_2. This provides convincing support for the suggestion that hydrocarbon gases exist at such great depths inside the earth that they cannot be of a biological origin.

The German deep hole. This hole is located in Windischeschenbach (Oberpfalz). The depth reached during the pilot drilling programme was 4 km (1990). From 3.2 km down the drill encountered increasingly common cases of highly concentrated salt brines with gases like methane and helium in open caves in the rock[16], but no petroleum.

The Swedish hole. The discovery of an oil and/or gas field in a location ruled out by the organic theory would settle the matter once and for all. Hence, Gold[5 (p. 172)] after studying various formations across the world, concluded that the Siljan Ring, Sweden was the best candidate for the job. This is the largest impact crater in Europe. According to the non-organic theory, the impact could have led to the formation of sizeable hydrocarbon deposits since the fractures created by the impact would favour the upward migration of primordial hydrocarbons. Although the field was located primarily on the basis of seismic data, numerous oil seeps have been noted in the small sedimentary deposits of the ring-shaped depression marking the crater, carbonates characteristic of oxidised methane occur in the area and seismic observations reveal zones of porosity stacked on top of one another. Hence the primary indications were favourable.

Finally, Gold succeeded in convincing investors and a project began to prospect for petroleum in the area. This was largely supported by the state-owned Swedish electricity utility Vattenfall. Drilling began in 1986. By late 1987 a depth of 6.5 km had been attained, but no large commercial deposits had been discovered[28]. Opponents saw in this the death knell of the non-organic theory (claiming the hydrocarbons detected were from the lubricating drilling mud injected into the ground during drilling), while Gold proclaimed a victory (claiming that significant amounts of hydrocarbons were discovered, and that large amounts lay beneath)[29]. Due to drilling difficulties, the project stopped short of its target. It can be said that this did not rule in favour of either proposition.

However, in 1989 the Swedish drilling company Dala Djupgas Produktions recovered a small quantity of oil from 6.7 km below the Siljan Ring. Again critics dismissed the find as being recycled drilling fluid. The tables were turned yet again when the same Company discovered oil in 1991 even at the shallow depth of 2.8 km at a nearby well, the horizon of the petroleum being basement granite[30]. Moreover the previous objection was nullified as the drilling fluid used in this case was water only. The proponents of the organic theory claimed that this oil was merely oil that had seeped into underlying fissures in the basement of rock from oil shales, since the petroleum found in the oil shales and that in the basement rock were chemically very similar. However, the non-organic theory explains this as being due to the upward migration of primordial petroleum; the two oils are similar because their common source is the same. The upward migrating hydrocarbons would have produced both the deep oil and the oil shales, the shale providing a good trap rock that could absorb the oil on its way up. Hence, the case appears to have recently swung in favour of the non-organists.

Only drilling in the future by men of the calibre of Col. Drake (the discoverer of the world's first oil-field), Dad Joiner (the discoverer of the giant E. Texas oil-field) and P. Higgins (the discoverer of the Spindletop oil-field) can yield the answer to this intriguing question.

Conclusion

The positive and negative features of the classical organic theory have been discussed. This has been the traditionally accepted proposal, much work having been done in this field. The rival non-organic theory has so far not been accepted due to the successes of the biological theory to date in elucidating certain properties of oil-fields. However, new results from deep holes across the world are difficult to describe in terms of the biological theory. It has been shown that these new observations can be naturally explained within the non-organic framework, and that the older biological supports (mainly relating to the presence of supposedly biological material in petroleum) can also be incorporated. Hence a duplex theory combining features of both theories may be the final victor. This would perhaps involve the enrichment of existing organic hydrocarbon deposits through non-organic hydrocarbons.

The abiogenic theory derives much of its support from diverse and exotic fields such as astrophysics, cosmo-geophysics, thermodynamics, nuclear geology, etc., and considerable strides in the comprehension of these fields have led to a impressive growth of information in support of the non-organic theory.

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MEETINGS/SYMPOSIA/SEMINARS

National Seminar on Bamboos and Exhibition of Bamboo Crafts

Date: 28–29 November 1996
Place: Bangalore

Seminar on status of bamboos in India and an exhibition and sale of bamboo products are arranged.

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National Symposium on Power System Instrumentation and Control

Date: 26–27 December 1996
Place: Bangalore

Topics include: Power electronics/power quality, Diagnostics and expert systems, Communications, DA/DSM, Grid operation/load despatch, Standards and standardization, Action plans, Thermal power plants, Protection, Optimization, Simulation and problem oriented papers.

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National Conference on Alternative and Renewable Energy Technologies

Date: 10–11 January 1997
Place: Hyderabad

Topics include: Solar thermal applications, Solar photovoltaic technology, Wind energy generation, Hybrid energy systems, Biomass conversion, Energy conservation and audit, energy recovery and efficient systems, Natural gas applications: fuel cell, co-generation, combined cycle power plants, Hydrozen energy, Alternative fuels and Ocean energy technologies.

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National Seminar on Coastal Zone Environmental Management: An Appraisal of the Contemporary Research and Development

Date: 12–14 February 1997
Place: Mangalore

Themes include: 1. Coastline and coastal zone (material and processes), 2. Remote sensing and coastal zone studies, 3. Coastal zone ecosystems, 4. Industrialization and coastal zone environment (impact of infrastructural development, waste disposal, etc.), 5. Water resources of coastal zone, 6. Coastal regulation zone (CRZ) (delimitation of CRZ, level of implementation of CRZ Act).

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