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The Deep Hot Biosphere by Thomas Gold. New York: Copernicus Books, 2001. 243 pp. \$20.00 (paperback). ISBN 0-387-95253-5.

There is much to be said about this important book, not only in the technical fields of geology, biology, and energy resources, but also in what it tells us about science and the social context in which science operates.

The central tenet of the author is something he calls the deep-Earth gas theory. The theory postulates that methane was incorporated into the solid Earth at the time of its accretion. Over geologic time, the gas has slowly and continuously percolated upward through the Earth's mantle. As methane approaches the surface, it becomes progressively depleted in hydrogen relative to carbon and forms deposits of natural gas, liquid oil, and coal.

The deep-Earth gas theory is anathema among most scientists in America and Europe, especially petroleum geologists. Petroleum geologists believe that virtually all of the world's oil and gas deposits formed from buried organic material. In a 1993 publication of the U.S. Geological Survey, John Apps and Peter van de Kamp expressed the prevailing opinion tersely:

Overwhelming evidence supports the belief that the world's natural-gas resources come from the decomposition of organic matter in sedimentary rock formations. (p. 81)

The primary reason that most geologists believe petroleum formed from buried organic debris is that petroleum molecules exhibit the unmistakable imprint of organic activity. Gold explains the organic signature by a corollary to the deep-Earth gas hypothesis that is both necessary and primary: the Earth's outer crust to a depth of several kilometers is inhabited by microorganisms that feed on the inorganic methane streaming up from below. The habitation of the Earth's crust by bacteria and archea is the source of the book's title: *The Deep Hot Biosphere*. Gold maintains that the organic markers found in petroleum originate from a processing by subsurface life—not from organic material originally at the Earth's surface that was buried. Surface life depends on photosynthesis. However, the organisms that live in the crust obtain energy chemically by oxidizing methane. Succinctly put, Gold's theory is that petroleum consists of “geology reworked by biology”, not “biology reworked by geology”.

Gold marshals several arguments in support of his hypothesis. Among these, he notes that there is a strong association of helium with natural gas. The standard biogenic theory contains no explanation for the helium association. Helium originates from deep within the crust and mantle of the Earth, and there is no logical reason it should be found in association with petroleum and gas derived from the reworking of shallowly buried organic material. The implication is that methane streaming up from the mantle acts as a carrier for helium. Nearly all geologists would allow that some inorganic methane out-gasses from the Earth's mantle, and some of them are probably open to the idea that liquid oil could originate in this manner. However, it is fair to say that most would ridicule Gold's idea that thick seams of coal could possibly form from methane. The standard hypothesis is that coal seams represent the buried remains of land plants, largely laid down during the Carboniferous Period about 360 to 290 million years ago. The modern analogue is the formation of thick deposits of unoxidized plant matter in peat bogs. The evidence that coal forms from buried plant material is most striking. When I was about ten years old, my father took me to an abandoned open-pit coal mine in Indiana. An oval-shaped

rock we found revealed the beautiful imprint of a leaf when cracked open. It is difficult to argue with this sort of find, but Gold has the peculiar genius needed to see the obvious: if the entire coal deposit formed from buried plant material, why do the coal layers contain only a few scattered vegetative imprints? He presents more compelling evidence. Coal contains only a fraction of the ash that it should have if it formed from land plants. Having spent a winter shoveling wood ashes out of my fireplace, the argument strikes home. Coal is usually found in thick seams that are continuous and horizontal. But in New Brunswick, Canada, there is a vertical seam filled with a mineral named Albertite, a type of coal. This occurrence is totally inexplicable according to the vegetative hypothesis, and is never mentioned in textbooks.

The implications of Gold's deep-Earth gas theory go well beyond the origin of oil, gas, and coal. The existence of a "deep hot biosphere" suggests that subsurface life may be the norm for Earth and perhaps other planets as well. If the surfaces of other planets appear to us to be devoid of life, perhaps it is because we are not looking in the correct place. Gold does a back-of-the-envelope calculation and finds that the mass of subsurface life on Earth may well exceed that of life on the surface. Although we think of microbes existing at subsurface temperatures above 100 degrees Celsius as extreme, it is surface life that is extreme. We live in an environment subject to the punishing radiation of the sun as well as periodic meteoritic bombardments. The origin of life itself is implicated in Gold's hypothesis. Gold points out a variety of reasons why it is more probable that life originated in the subsurface than on or near the surface.

The standard geophysical theory is that all earthquakes originate in the release of stress in the solid Earth. But if a pocket of methane gas is released catastrophically, an earthquake can result. The historical record contains numerous eyewitness accounts of gas eruptions accompanying major temblors. The idea is not new. Before he committed suicide at Nero's insistence, Seneca (3 BC–65 AD), the Roman author of *Natural Questions*, suggested that earthquakes were probably due to the subsurface movement of air.

No one, I suppose, can doubt that there is nothing so restless, so capricious, so fond of disturbance as air.

In 1963, the American geologist M. King Hubbert (1903–1989) published a remarkable essay titled "Are We Retrogressing in Science?" One of his theses was that specialization was killing geology. "Don't let them specialize you", he advised a colleague. Hubbert argued that geological phenomena almost always have both physical and chemical aspects, as well as characteristics that could be described as falling within the traditional domain of descriptive geology. Biology is also relevant to many geological problems. It follows that a specialist will be handicapped in attempts to understand most geological phenomena. The curse of specialization was recognized long ago. In his monumental work, *The Outline of History* (1921), H. G. Wells (1866–1946) noted:

We have still to discover how to preserve our centers of philosophy and research from the caking and darkening accumulations of narrow and dingy-spirited specialists. (p. 349)

The problem grows worse each passing decade, but it is apparent that in Thomas Gold we have a striking counterexample. Gold exhibits the irrepressible and universal genius that we recognize in Aristotle and Leonardo da Vinci. In a remarkable passage in *The Deep Hot Biosphere*, he describes how he had just obtained a black, pasty substance from a borehole in Sweden and was anxious to immediately analyze it. No laboratory was at hand, however, and Gold was shut up for a weekend in an apartment without access to even a drugstore. Most people would have waited and sent the mysterious paste to an analytical laboratory. Not Gold. He started analyzing his sample by testing to see if it would dissolve in hot water and detergent. Then he unscrewed a magnet from a door hinge to test for magnetic properties. When the material was still workable after a night in the freezer, Gold concluded that it contained very little water. He used paper towels as a sort of a crude chromatograph and cut the mysterious substance with a knife. Because the cut surface was glossy, Gold concluded, “the particle size could not be much larger than the wavelength of light”. The versatility and range of knowledge exhibited is remarkable.

It is fair to say that *The Deep Hot Biosphere* does not give an entirely balanced treatment of the subject hypothesis. Rather than dispassionately listing and evaluating evidence that both supports and tends to falsify the deep-Earth gas theory, Gold tends to mostly accumulate the arguments that support his thesis. It is a forgivable approach. The alternatives already dominate the scientific and popular literature; Gold can scarcely be criticized for not giving them more time. Peter Ramus (1515–1572) is said to have written a work titled *Everything That Aristotle Wrote Was Wrong*, and Paracelsus (1493–1541) publicly burned the revered works of Galen and Avicenna. When dogmatic belief prevails, it is sometimes necessary to resort to a frontal assault.

There is a difficulty with the deep-Earth gas theory. In order for the Earth to continuously degas methane over geologic time, the methane had to have been incorporated and retained in the body of the Earth at the time of its accretion. The Earth had to accrete cold, because a hot, molten Earth would have degassed its volatiles during or shortly after formation. Gold inexplicably states that up to about 1950 it was thought that the Earth had accreted hot instead of cold. He then asserts—without any reference to scientific study other than his own—that the Earth was subjected to only partial melting during its accretion. This scenario is exactly the opposite of what we find in the literature. The old idea is that the Earth accreted cold, warmed up from radioactive heat generation, and started to degas. This is the scenario invoked by W. W. Rubey in his classic 1951 paper, “Geologic History of Sea Water, an Attempt to State the Problem”. However, it is now widely believed that the Earth accreted hot, not cold. For example, in an authoritative review published in 1990, George Wetherill stated: “at the present time there are not even any semiquantitative theories extant that lead to an unmelted Earth”. Data from noble gasses also strongly imply that the

young, hot Earth degassed almost completely shortly after its formation. In a review paper published in 1997, Stuart Ross Taylor concluded that the relative abundances of xenon isotopes require that up to 80 percent of volatile outgassing occurred within 50 million years of Earth's accretion. If this is what happened, then the interior of the Earth must be devoid of methane in the quantities required by the deep-Earth gas hypothesis. Of course, we don't know for sure if the Earth formed hot or cold: we were not there. But nevertheless a good deal of the relevant science appears to be missing from *The Deep Hot Biosphere*.

There is another aspect of the deep-Earth gas hypothesis that Gold does not discuss. He never considers the effect of carbon recycling into the Earth's mantle by the process of subduction. Each year, about 10^{11} (100 billion) kilograms of carbon is carried down into the mantle by the process of subduction; less than half of this carbon is returned to the surface by volcanic outgassing. This is a very significant process. Extrapolated over the Earth's lifetime of 4.5 billion years, the amount of carbon that has been delivered to the mantle is equal to the entire near-surface inventory of 10^{20} kilograms. Thus it is entirely possible that the source of the methane that streams up from the mantle (in Gold's hypothesis) is not primordial, but recycled carbon that was introduced by subduction. This interpretation is more consistent with a hot young Earth devoid of volatile constituents.

The Deep Hot Biosphere is a highly interesting and important book; it should be required reading for every geology student. This does not necessarily mean that the deep-Earth hypothesis is correct. The debate will continue; it is unfortunate that there will be little serious discussion among American petroleum geologists: their reaction to the abiogenic hypothesis has mostly been an hysterical affirmation of close-mindedness. I am reminded of the rhetoric of that distinguished Egyptian monk, Cosmas Indicopleustes (c. 490–585 AD). Cosmas could not understand how any reasonable person could take seriously the ridiculous pagan theory of a spherical Earth. In his memorable book, *Christian Topography*, he attacked the spherical-Earth theorists:

Ye advance arguments altogether incredible . . . [and] ye advance arguments which are self-contradictory and opposed to the nature of things . . . How great is your knowledge! How great your wisdom! How great your intelligence! How great your inconsistency! . . . let each one of you who has sound vision and the power of reasoning justly turn the earth round whatever way he pleases, and let him say whether the Antipodes can be all standing upright in the same sense of the expression. But this they will not show even should they speak unrestrained by shame. Such then is our reply to your fictitious and false theories and to the conclusions of your reasonings which are capricious, self-contradictory, inconsistent, doomed to be utterly confounded, and to be whirled round and round even more than that unstable and revolving mythical sphere of yours. (p. 136)

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Investigations of the Paranormal by Tony Cornell. New York: Helix Press, 2002. \$36.00. ISBN 0-912328-98-3.

This book is by a Cambridge University graduate who apparently has lived in Cambridge all his life. The book is essentially a detailed account of his career as an investigator of the paranormal. At the end he makes some general conclusions.

The book is in four sections. The first has eleven chapters on hauntings and the second, nine on poltergeists. Then there is a section on mediums and mediumship which contains seven chapters, and finally the last section on conclusions has three chapters.

The general attitude throughout the book is rather lighthearted. The author's investigations are a monument to the need for skepticism about all claims of the paranormal. There are several examples of blatant fraud and two of self-deception.

On the other hand, it would be difficult for anyone who is open-minded and who reads the book thoroughly not to conclude that the author has observed phenomena which undoubtedly do occur but which are not explicable in terms of present knowledge. The book is strong on local history in the University of Cambridge, and most of the investigations described take place in Cambridge and the surrounding towns.

The book starts off with an account of ghosts alleged to haunt in the University. Some turn out to be illusions, although other accounts are open-ended in conclusion.

In Chapter 3 there is reliance on answers to Ouija Board questions about a ghost which is alleged to haunt a remote inn. Cornell believes the people who claim to have seen the ghost were overcome by the stories they had heard and created her image.

Then in Chapter 6 there is a story called "Seen and Unseen Ghosts" in which a number of people claim to have seen a ghost, this time a ginger-haired man in a green jacket. Cornell is more positive to the reality of the occurrences here