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RESEARCH ARTICLE

Earthquake Triggering: Verification of Insights Obtained by Intuitive Consensus

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Abstract—Up until 1980 seismology was focused entirely upon data collection, the long-term study of tectonic processes, and limited surface-level measurements. Formal research on earthquakes was almost at a standstill despite the urgent need to discover reliable and measurable precursors in support of a system for short-term prediction. In the period 1975–1978 the author chose to interview eight intuitive experts who had proven their abilities in domains other than seismology. He asked them identical questions about the physical process involved in earthquake-triggering and associated precursors, and then compiled their consistent responses into a consensus. The accounts agreed well with one another and offered a number of insightful and possibly new directions for seismological research. Re-examination of these intuitive findings thirty years later, in the light of the many subsequent discoveries reported in mainstream geophysics journals, revealed that the expert intuitives had provided novel, significant, and strikingly correct information on earthquake-triggering and related precursors. This exemplary result suggests that skillfully applied intuitive inquiry could play a significant role in future seismological and geophysical studies, as well as in scientific research generally.

Keywords: earthquakes—intuition—intuitive consensus—expert intuitives—earthquake triggering—seismology—geophysics—prediction—verification—nuclear activity—precursors—tectonic plates —atmospheric electricity—electromagnetism—faults—earthquake lights—solar wind—thermal anomalies—solar activity—magnetosphere—ground gases—earth tides—planets—atmosphere—weather changes—animal behavior—human-caused earthquakes

Intuition—Another Way of Knowing

The discovery portion of science typically includes insight into the nature or concept of a problem being investigated, followed by methodical, rational exploration, formulation of hypotheses, and then verification of the hypotheses. Anyone mentioning science almost always refers only to the latter steps of the process: validating the hypothetical information according to consensus-based, rationally derived contemporary methodology. Alluding to the first step—the more intuitive part—in straight science means touching on a "taboo," yet the history of science indicates that many major advances have been achieved from intuitive breakthroughs (Poincaré 1952, Koestler 1964, Harman & Rheingold 1984, Palmer 1998).

Many crucial ideas that led to the expansion of scientific knowledge relied upon intuitive insights. They arose out of sudden perceptions, subtle hunches, serendipitous associations, and even dreams, as the record of major discoveries convincingly reveals. These are mainly non-rational mental events, not explainable by contemporary models of the brain and mind and—except for transpersonal efforts—not even an acknowledged part of present-day psychology. They fall collectively into the category of intuition, or the direct reception of knowledge into the mind without the aid of reason, memory, or the senses (Vaughan 1979, Peirce 1997, Palmer 1998). Intuition has been observed to be a powerful source of new ideas, hypotheses, and understanding in many fields of knowledge as well as in various aspects of daily life. It exists in the human mind as an innate ability, and can be trained and developed into a refined skill through deliberate desire, intention, and effort, as demonstrated by many "expert intuitives" (Kautz 2005, Klimo 1987, Radin 1997, Shealy 2010, Schwartz & de Mattei 1990). These individuals have been able to access many kinds of new knowledge, including even highly specialized information not already known by anyone.

Since intuition is rarely mentioned in connection with the scientific discovery process, it is important to elaborate how it has been experienced historically and deliberately applied to generate new, accurate, useful information.

The Nature of Intuition

Intuition is popularly (and ambiguously) regarded as a flash of insight, a gut feeling, a "psychic hit," and even an unconscious reasoning process. A much older tradition bespeaks of it as an innate human capacity (Kautz 2005, Palmer 1998). This kind of "direct knowing" was inherent in Greek philosophy (*nous*), Gnosticism, Eastern religions, and other early cultures as both a root belief and a common practice. It persisted over most of the world during the centuries to follow, up until the scientific revolution in the 17^{th} century in the Western world. It then took second place to the empirical, sensually based, materialistic, and rational methodology of science, which became the favored means for gaining new knowledge about the natural world. Modern science has now become the accepted arbiter of validity for new knowledge from any source.

Intuition is not a favored topic for study within science, which regards it as too subjective for rational consideration and therefore allied with the superstitions of past generations. Today it is barely mentioned in psychology and psychiatry textbooks and has never been the subject of systematic study. This exclusion is historically understandable, and partially valid, because the metaphysical assumptions on which modern science is based insist on objectivity, measurability, repeatability, and certain presumptions about causality. These assumptions are not fully satisfied by "phenomena" such as intuition (Barrow 1988, Harman & Clark 1994, Popper 1959, Sperry 1987). Thus, all that science can do with intuition is to verify empirically whether an alleged intuitive insight is or is not valid, according to its own accepted scientific criteria, and whether the insight might be explained through current physical understanding. Until the latter half of the 20th century, science was reluctant to do even this much.

The Evidence for Intuition

Several decades of careful parapsychological research have now verified firmly that (1) intuition actually exists as a mental capacity (Palmer 1998, Radin 1997, Vaughan 1979, Targ & Puthoff 1974) and (2) it contradicts one or more of the underlying assumptions of current physical science (just listed): objectivity, measurability, repeatability, and certain presumptions about causality. Deeper scientific exploration into the nature of intuition is difficult, therefore, and is not fully possible in view of these assumptions and other derived limitations of modern science's means and models of investigation. A few recent studies seek to explain intuition within the latest models of human consciousness, as exemplified by several recent multidisciplinary international conferences on the subject.[1] Similar efforts seek a place for intuition within the various "theories of everything" that have emerged out of the paradoxes of quantum physics; for example, Bohm's Implicate Order (Bohm 1980), Laszlo's A-Field (Laszlo 2003), Pribram's holographic model (Pribram 1987), and Hawking's and Mlodinow's M-theory (Hawking & Mlodinow 2010). These theories derive largely from the observation that both intuition and modern physics require the transcendence of ordinary conceptions of time and space, and the fluid, unilateral flow of events and information. While such speculative attempts are inspiring and suggestive of metaphors, none has yet found proof or won broad acceptance, even apart from their putative intuitive association. A satisfying scientific explanation of intuition is still lacking.

The classic Western philosophers—Descartes, Locke, Kant, and others — had their own notions of intuition, although most combined it with per-ception and intellect (Kenny 1997, Tarnas 1991). Freud had no use for intuition, but his follower Carl Gustav Jung considered it to be one of his four fundamental "psychological types," along with sensing, thinking, and feeling (Jung 1971); the Myers–Briggs personality indicator utilizes these types (Myers et al. 1998). Philosopher Henri Bergson saw intuition as the essential ingredient of metaphysics and an evolved form of instinct that reveals the essence of things, apart from the symbols adopted for them (Bergson 2002). Michael Polanyi's tacit knowing referred to unaware, contextual personal knowledge that a person carries hidden in his mind (Polanyi 1966). Eminent neurobiologist Roger Sperry (1987) acknowledged intuition fully, and courageously assigned it to the right brain. In general, these philosophers and scientists sought to clarify the innate, direct-knowing quality of mind, apart from ordinary perception, intellect, senses, and brain. All were led to essentially the same definition of intuition as given above, though still not in scientific or familiar terms. The "direct knowing" capacity of intuition has always been an integral part of Eastern philosophy, which regards it as a valid and significant means for gaining deep knowledge, thus an alternative to classical science (e.g., Aurobindo 1993). Today limited systematic explorations of intuition are taking place within the humanistic and transpersonal subfields of psychology (Palmer 1998, Vaughan 1979, Walsh & Vaughan 1993).

Intuition at Work

The importance of intuition is most apparent today through the role it continues to play in creativity, the arts, humanities, and human interactions generally. Many psychotherapists and physicians are well aware of the important place of intuition in their practice. The most firmly established attributes of the human intuitive faculty are provided by the carefully conducted scientific experiments in parapsychology over the last century, as mentioned above. This work has shown conclusively that various kinds of specific information not accessible by ordinary means, not predictable in any real sense, and in some cases not known by any living human being can be accessed through intuition's direct-knowing process (Mishlove 1975, Radin 1997, Targ & Puthoff 1977). Moreover, the individuals who have manifested this capacity—called here expert intuitives—are not obviously exceptional in any other way. Basic intuitive capacity appears to be natural, not supernatural, and virtually universal. In order to function, it need only to be enabled, like learning to walk and talk.

A ten-year research study at the author's Center for Applied Intuition in the 1980s again showed that intuition as defined above is a genuine mental faculty. This work relied upon the services of several expert intuitives, and was applied practically in a dozen knowledge-dependent fields: recovery of ancient history and language, geophysics, nutritional science, archaeology, nuclear technology, medical problems, personal counseling, business consulting, and others (Kautz 2005, Grof & Kautz 2010). Intuition showed itself to be not only a significant facet of the human mind but also a practical tool for human endeavors that depend for their success on new information and knowledge—most especially in science.

There is no shortage today of expert intuitives. Most of them prefer to remain inconspicuous, however, and can be difficult to locate. Then they must be carefully tested for expertness before being relied upon. The personal option remains open: Anyone may choose to develop his own intuitive capacities rather than relying upon experts.

While the existence issue for intuition has been settled, there remain many questions on the conditions under which accurate intuitive perception may take place deliberately and under control. For example: What are the limits on the types and depth of information that may be obtained intuitively? What factors govern its accuracy and clarity? How does intuition relate to familiar mental activities such as imagination, memory, dreams, learning, and cognitive function? Where does the new information come from? And what are the psychological/neurological mechanisms behind the intuitive process? While answers to most of these questions are not presently available, the same type of questions may be asked regarding other human capabilities such as reasoning, language, and creativity. We humans have learned to utilize these capacities effectively even though we cannot fully explain the physiological and brain processes involved and all their limitations. Similarly, as we wait for an acceptable explanation of intuition, we are free to develop and use it.

Seismology: An Active but Slow-Moving Science

Seismology, the subfield of geophysics concerned with earthquakes, began with the development of the seismometer. This simple device enabled the detection, recording, and eventual analysis of the heavy vibrations that propagate outward through the earth from the hypocenters and connected faults of earthquakes.[2] A global network of thousands of seismometers gradually evolved and generated sufficient data to permit detailed global maps of both the locations of earthquakes and the propagation of the seismic waves through the entire globe, which provided indirect information about the composition of the earth's interior. The first early earthquake theories soon evolved.

It became known by 1970 that major earthquakes are produced mainly at the boundaries of the dozen or so rigid tectonic plates that the thin crust of the earth comprises (Lay & Wallace 1995, Gubbins 1990, Lee, Jennings, Kisslinger, & Kanamori 2004). They float on the more plastic mantle of rock underneath, move slowly and unevenly from 1 to 6 centimeters per year, presumably in response to dynamic, circulatory convective mass movement within the earth. The quakes occur erratically along the boundaries when new plates are created where magma wells up from the mantle and solidifies, where existing plate edges are absorbed back into the mantle (subduction), or with internal cracks, or faults, where plates grind against one other and occasionally slip. Whenever the accumulated stress in these rock interfaces is suddenly released, a chain of ruptures takes place along the fault, producing an earthquake. This sudden release of energy, sometimes very great, generates body waves, which propagate outward, shaking the ground over a wide area.

The motivation for seismological studies arises mainly out of the societal need to reduce the great cost in human life and property resulting from medium-to-large quakes. This need translates into two applications, namely earthquake engineering, the technology for designing earthquake-resistant structures (quite successful), and earthquake prediction or forecasting, the capacity to anticipate the catastrophic ruptures far enough in advance and with sufficient accuracy to allow a constructive and protective human response (not so successful). Earthquake-prediction research involves experimental and theoretical studies of both long-range causal mechanisms and the short-range earthquake-triggering process. The latter includes the search for specific precursory phenomena that might be continuously monitored through observation or instrumentation (Summary of Technical Reports 1980, Earthquake Prediction 1996, Geller 1997, Vogel 1979, Andriese 1980, Simpson & Richards 1981, Sykes, Shaw, & Schultz 1999, Kanamori 2003, Hough 2009).

It is not possible to make direct measurements of the buildup of stress along faults, which are relatively deep. There is therefore no way to know exactly where and when any particular point of high stress will rupture, and how much energy will be released when it does. These quantities can be estimated very roughly by analyzing the patterns of earlier quakes in one broad area, by measuring the strain along accessible faults, and by measuring variations in the propagation velocity of waves through deeper stressed areas. The results permit some long-range prediction of the time, location, and magnitude of future earthquakes. They show where building construction should be improved, but are much too crude and unreliable to allow short-range prediction. At the other extreme, short-term prediction (up to about a minute) is possible by transmitting the first indication of a large shock to communities within the radius of possible damage. High-speed trains may be slowed down,[3] nuclear reactors shut down, utilities turned off, and individuals in hazardous positions alerted. Similar warning systems are now in place around oceans to take advantage of the delay, up to several hours, before a tsunami wave arrives after an undersea earthquake.

While the local physical mechanism that triggers the release of stress is not understood, it is only reasonable to suspect from physical science that one or more precursors[4] ought to exist and be measurable in earthquake-prone areas, in order to enable short-term prediction—from a day to a few weeks, say—thereby allowing effective hazard-reduction measures to be taken (Rikitake 1975, Cicerone, Ebel, & Britton 2009). Despite various theoretical possibilities, laboratory experiments, and field studies, no reliable and broadly useful precursors have been identified and applied to date (2011) for prediction purposes.

The Earthquake-Prediction Game

The inability of seismologists to provide useful short-term earthquake prediction opens up the field to anyone who thinks he might do better. Since scientific knowledge is not necessarily required for discovery—only for validation of a claim or hypothesis—a useful earthquake precursor could be discovered accidentally by an amateur (even a psychic!) without a background in seismology. Every damaging shock brings into the media a flurry of announcements from persons who want to play the earthquake-prediction game. The public fascination with prediction of all sorts feeds this movement. Amateurs typically claim to have discovered a solution to the earthquake prediction problem in the patterns of eclipses, the number of notices for lost cats, occurrences of geomagnetic storms, unusual cloud formations, and the like.

Such claims never work out, of course, and even if a prediction is accurate it is worthless by itself. To be useful for practical public prediction, it must first be demonstrated to be consistently valid for a variety of types of earthquakes (shallow and deep, different fault types, a range of magnitudes, under land and water, etc.); it must lead to predictions reasonably precise in location and time; it must be readily observable or measurable with available instruments; and most important, it must be verified by scientists and supported by public officials who will stand behind it. Such validation requires a coordinated effort by specialists, can take years or decades to develop and verify, and is very expensive—well beyond the bright idea of a naïve amateur. Publicly useful short-term predictions must carry sufficient certainty to authorize the inconvenience and cost of major evacuation, shut-down of business districts, putting hospitals on alert, stopping trains, closing off large bridges, draining dams, and other hazard-reduction precautions. Moreover, they must initiate these various actions without inducing irrational public behavior (e.g., fear, disorientation, panic).

Most public predictions by amateurs are announced only after the shock, or are so loosely stated as to be unverifiable, or are incorrect even when timely and precise. Followup is rare: Failures don't make interesting news. We can only wonder why these persons are so zealous in announcing their shaky predictions to the media in the first place. The enthusiastic amateur who speaks out about his grand new solution to earthquake prediction is not only misleading his audience but is behaving irresponsibly. After all, it is very easy to make a prediction—anyone can do it. It is not so easy to predict correctly, significantly, and convincingly. (The very term *prediction* is ambiguous on this score.)

Predictions offered by seismologists are more credible but are infrequent, conservative, qualified, and apply only to small earthquakes and long-term possibilities. They are derived from extensive data, collected and analyzed for particular areas that have been studied for a long time. Stated as probabilities rather than certainties, they are not useful as warnings for immediate action. Because seismologists KNOW that they cannot predict earthquakes on the basis of their established seismological methods.

China, the scene of many tragic and damaging earthquakes, has a wide monitoring system in place and a few impressive predictions to its credit. One in 1975 resulted in the evacuation of Haicheng, a town of a million people, two days before a large shock destroyed the town (K. Wang, Chen, Sun, & A. Wang 2006). Only two thousand lives were lost. Still, the Chinese have had many more failures, both predictions without quakes and quakes without predictions. The search for a basis of practical prediction continues.

The State of the Art in 1980

Up until 1980 theoretical work on earthquake triggering was focused entirely on the behavior of stressed rock under the high temperatures and pressures believed to be prevalent at the depth of typical hypocenters, including especially the role of water in this unfamiliar environment. Findings were derived from wave-propagation records of seismometer data, extrapolation from laboratory and surface-level measurements on stressed rock, and a few relatively shallow bore-hole experiments. Several ground-level precursors that might be useful for prediction purposes were identified in particular areas: tilt, slip, elevation, and subsidence of the ground; micro-earthquake swarms; patterns of foreshocks; changes in well-water levels; seismic "gaps" without recent activity; and the release of radon and other ground gases. Other candidate precursors were reported for particular quakes, but their significance remained conjectural. They were not being tested or examined broadly: unusual animal behavior, the consequences of filling of dams, chemical changes in ground water, earth–tidal maxima, cloud formations, telluric electric currents, ground resistivity changes, air-pressure variations, and glows in the lower atmosphere.

By 1980 there was no precedent in seismology to suspect that above-ground factors could be causative or even indicative of earthquake triggering and changes in preliminary precursors (Vogel 1979, Summary of Technical Reports 1980, Adamo & Enns 1980, Andriese 1980, Simpson & Richards 1981, Rikitake 1981). Even later no specific hypotheses of above-ground effects or indicators were being investigated, and no scientific effort was directed into such possibilities (Earthquake Prediction 1996). Data that might have been relevant were poor and unconvincing. For example, abnormal animal behavior (see EQA section below, ***EQA—Abnormal Animal Behavior***) and atmospheric glows (EQE and EQL) had been anecdotally reported near earthquakes for decades, and could have been taken as a clue to novel atmospheric precursors, but they were generally assumed to be superstitions, insignificant, and not related to earthquakes.

On the political front, the U.S. national budget for earthquake research remained at a low level during the 1960s and 1970s (and is still low), despite the occurrence of large, damaging, and costly earthquakes in the U.S., and abroad. Not until 1977 was the National Earthquake Hazards Reduction Program established in the United States. Similar programs began in Japan (1964), China (1956), and the Soviet Union (partially in the 1960s, mainly in 2004). While foreign observations and research increased during the 1970s, the reports were not taken very seriously in the U.S. (only much later). Seismological research seemed to be moving as slowly as the tectonic plates themselves.

Purpose and Approach

In order to spur progress on earthquake research, this author chose in 1975 to apply a method of multi-intuitive inquiry called intuitive consensus to generate new information on the triggering process and associated precursory phenomena. Similar intuitive efforts in other fields had achieved some impressive successes (Kautz 2005).

The inquiries were carried out in 1975–1978 with eight members of a team of "expert intuitives" at the Center for Applied Intuition, a San Francisco organization that was at the time investigating intuition and its applications.

The broad purpose of this early study was to demonstrate by example the validity and usefulness of properly conducted intuitive inquiry as a means for generating new knowledge, outside of the scientific approach. Specifically, it sought to identify new aspects of the earthquake-triggering process that would merit future research, and to provide relevant technical details in support of this research. It was believed that the intuitive findings, called here insights, if sufficiently credible as ideas and hypotheses, could open the door to their verification by accepted scientific methods of experimentation, validation, and proof, and eventually find subsequent application in research studies on earthquake triggering or even an actual prediction system.

This effort did not attempt to provide a full explanation of earthquake triggering, to predict particular earthquakes, or to predict what kind of earthquake research efforts would actually take place in the future, but only to generate findings that could be verified if future research were actually carried out. Nor did this study attempt to prove the existence of intuition, which has already been adequately carried out, or to show that intuitive information is always accurate and factual, which is neither true nor possible.

Method of Inquiry

The original study comprised (a) definition of the main topic and sub-topics chosen for inquiry; (b) formulation of questions, based upon our understanding of the earthquake-triggering process available at the time (1975); (c) selection of expert intuitives; (d) execution of the inquiry sessions with them, including recording and transcription; (e) identification of agreeing responses (consensus); and (f) comparison of the consensus with already existing knowledge, leading to brief reports and eventually to this report.

Prior experience with intuitive inquiries had shown that the formulation of the questions to be posed to the intuitives is critical to success. Namely, they should be specific, focused, clear, well-motivated (that is, not arising from curiosity alone), and without expectations, biases, or implicit assumptions. These guidelines were followed closely, conditioned only by the fact that the geophysical understanding of earthquake triggering at the time was very incomplete, and sometimes incorrect (as revealed later). In the absence of an overall physical model of the triggering process, and without knowing even the particular physical quantities (precursors) indicative of forthcoming quakes, the questions were necessarily more broad than deep and more exploratory than strictly focused. In retrospect, some seem today to be rather naïve. (It might be looked at as similar to asking for the cause of cancer, which can be recognized today as a meaningless question.)

Of the eight "intuitive experts" selected for participation, five were interviewed initially (1975) and three more two years later. None had prior formal training or experience with seismology or geophysics, or more than a typical public exposure to the subject. All were qualified because (a) they were experienced in intuitive work, having demonstrated their skills in prior inquiries on other topics, ranging from personal to historical to highly technical, and (b) these prior tasks revealed their individual answers to be responsive and self-consistent whenever the questions posed to them were clear and founded upon well-established knowledge. Their responses were also found to be accurate whenever independent validation was possible and was actually carried out.

The inquiry sessions with the intuitives were conducted independently with the same set of questions, a procedure that made it possible to compile and compare their responses. Previous investigations (Kautz 2005) had demonstrated that such consensual findings, created from a substantial majority of agreeing responses, reduces the probability of incorrect answers. Responses that were not in good agreement were excluded from the reported consensus, except as specifically noted here, but were retained for their suggestive value for any future inquiries.[5]

All interviews were conducted by the author. Special care was exercised to avoid unnecessary explanation to the intuitives beyond that needed to make the questions clear, and to prevent accidental leakage of the interviewer's personal beliefs and expectations derived from his previous work in seismology.

Verification

Insights generated through intuitive inquiry are initially unproven and must be regarded as hypothetical, just like new information from any source. Within our present societal paradigm, they must be validated by independent means, usually scientific, before they can be regarded as substantiated and factual. To this end, the second phase of this study (2011) consisted of two steps, applied to the insights obtained in 1975–1977.

First, in order to validate that the insights had a genuinely intuitive source, it had to be shown that they were novel, meaning that they were not already known to the intuitives at the time of the inquiry. To establish prior ignorance of information is normally very difficult, but in a well-documented field such as seismology the flow of published technical information provides a timely, reliable, and thorough measure of the state of expanding knowledge over time, with only a year or two delay. By comparing the new information against the scientific record before 1980, say, we can be certain that the intuitives had no separate access to it through scientific or media channels.

Second, in order to show validity, the intuitive insights must be shown to be accurate in content, by comparing them with findings reported in scientific articles and books published after the inquiry. They should also not follow obviously and logically from what was known earlier. This published evidence was taken from scientific journals, and occasionally from less authoritative but substantially valid sources—for instance, when the latter contained acceptable observational or experimental data even though their interpretations or explanations were questionable, or when an explanation was credible though the data themselves were doubtful.

The degree of consensus among intuitives was high. Two early, inconspicuous publications (Kautz 1982, 2005) reported these early insights and compared them favorably with a few discoveries in geophysical research. It is quite certain now that these early publications did not stimulate ongoing seismological research, as originally hoped, even though (in retrospect) they could have done so if the seismological community had been open to such new ideas.

This present report arose out of thorough verification and substantiation, based upon published geophysical research between 1980 and 2011. The accuracy assessment was carried out in observable or potentially measurable terms, namely through the candidate precursors described by the intuitives. These are discussed separately in the following sections, abbreviated here for convenient cross-referral:

EQE—Atmospheric electric fields
EQM—Electromagnetic signals in the earth and lower atmosphere
EQI—Upper atmospheric and ionospheric field variations
EQTh—Thermal anomalies on the earth's surface
EQL—Earthquake lights, atmospheric luminescence

EQS—Solar activity, solar wind, geomagnetic field changes
EQP—Planetary effects
EQT—Earth tidal effects (solid and ocean, moon and sun)
EQG—Ground gas emission
EQF—Centrifugal forces inside the earth
EQW—Weather changes
EQA—Abnormal animal behavior
EQN—Nuclear and other radiation
EQH—Human activities

These fourteen candidate precursors are not of one type but varied. They seemed originally to be fairly distinct but turned out instead to be highly interdependent. It is still not fully known which are genuine rather than merely suggested; which are giving rise to which others; which are valid only in combination with others; and which are only indicative rather than causative of triggering. Some seem to be active only for particular kinds of earthquakes—locations, types, depths, magnitudes—or in the presence of new factors not yet discovered. Several cited by the intuitives were completely new, while others had already been explored in seismology but were not mentioned by the intuitives (and are not discussed further here). Finally, one precursor was found to require very costly instrumentation; it may contribute later to an understanding of triggering though it is not practically measurable for prediction purposes.

Earthquake research, including triggering and prediction, has for many decades been carried out in the US almost entirely by the U.S. Geological Survey (USGS), with more recent participation by the National Aeronautics and Space Administration (NASA), and supplemented by policy and overseeing bodies: the National Science Foundation (NSF), the National Research Council (NRC), and professional organizations such as the American Geophysical Union (AGU).[6]

General Description of Intuitive Findings

Overall, it is impressive that several of the intuitives' insights, which at the time of the inquiry were unknown, unexpected, improbable, and contrary to existing theories, have since been verified by mainstream geophysical research. A number stated ambiguously were not fully assessable, but none of the consensual results have since been proven to be downright wrong.

We review first the broad intuitive findings that emerged from the inquiries. The full record of the consensus would occupy a book and would be very repetitive. A small number of typical and more eloquent excerpts are included in this article, to illustrate the flavor of the intuitives' typical responses to the questions asked of them. They reflect only weakly the full breadth of content.

The intuitives explained that there is no single cause of earthquake triggering; rather, multiple, interdependent factors come together to create the trigger:

> There is no one particular final [triggering] force except that which would be considered as the content [combination] of electromagnetic and vibrational energies upon the molecular level within the earth crust itself. . . . It is the combined forces of gaseous pressure, electromagnetic activity—which must be elaborated upon[7]—the pressures of centrifugal forces combined with the normal expansionary pressures of any heated matter. When all of these reach a critical point the final triggering of the quake [takes place through] the electromagnetic charge that has been built up. [KR][8]

> The trigger is not one thing but a combination—one factor in one case, another factor in another. Mainly, though, external energy is coming in from two sources, one external to the earth and the other inside of the earth, and there is an interaction between these two. [BR]

> [What kind of forces are acting upon the rock at the point of fracture or sliding?] These are static pressures that come about from electrostatic, electromagnetic, and nuclear pressures. The electrostatic and electromagnetic forces act not directly on the epicenter [hypocenter?] but in the surrounding area, while the nuclear force acts directly on the epicenter [hypocenter]. [AA]

> There is a combination of the forces within the earth itself . . . together with the electrical forces from the outside which are coming together and joining, even as you would see a discharge of energy between clouds. Here you have solid clouds. There will be an eruption when these two meet, an explosion. That is the mechanism of it, for the earth is charged and so are these forces. They are charges, particles of charged energy. [AA]

> There are two forces which would account for triggering the final activities of quakes. In the centermost [part] of tectonic plates the centrifugal force of the planet in its axis of rotation combines with the thermal expansionary forces of the molten masses beneath the surface to [cause] movement along the inner structures, toward the outer surfaces of the tectonic plates, wherein there is the gaining of the highly charged magnetic and electromagnetic forces and the accumulation of both gaseous and aqueous forces. [KR]

Most surprising in these responses were the variety, types, and locales of phenomena that were said to be involved in triggering but which had never been considered or even suspected in seismological research. This prior research had focused entirely upon mechanical processes and measurements in the crust of the solid earth and below it. It did not extend to physical energies above the earth's surface and certainly not to the farther reaches of the atmosphere and outer space. The intuitive version of the triggering process sounded as if it is as much electromagnetic and plasmic as it is mechanical and thermal. The most significant precursors, it said, were more likely to be found in the atmosphere, ionosphere, and space than in the ground.

We consider now in detail the intuitive responses, first those clearly verified by subsequent geophysical research (the next section, **Precursors Well Verified by Intuitive Insights**), then those only partially verified and therefore leading candidates for future research and verification (the following section, **Precursors Partially Verified by Intuitive Insights**), and finally those that are too vague to be verifiable (the last section **Candidate Precursors Not Verified**). They are classified according to precursor.

Precursors Well Verified by Intuitive Insights

EQE—Atmospheric Electricity

Prior to 1980 the static atmospheric electric field (about 100 V/m at the surface) and its daily variations were recognized but only partially understood (Bibliography: International Center for Earth Tides no date, Chalmers 1967, Vonnegut 1973, Anderson & Freier 1969). Sporadic luminescences such as ball lightning, "earthquake lights," and St. Elmo's fire (see subsection on EQL below) were presumably of electrical origin, but the high voltages necessary for ionization of the air had not yet been well explored and explained. The role of electricity in weather phenomena such as tornadoes, storms, clouds, and lightning was recognized, though not well understood, and except for lightning there was no recognition of strong electromagnetic activity in the atmosphere (see EQW below). While lightning was properly seen as a very powerful electric discharge between clouds and earth and among clouds, the physical mechanisms behind its occurrence were regarded as complex and mysterious (as are some aspects even today) (Orville 2009). Farther out in near-earth space, the ionosphere, and the earth's magnetosphere, while obviously electrical in nature, were seen as too far out to be related to lower atmospheric processes and certainly not to earthquakes.

In this historical context, the intuitives' statements about significant above-ground electrical activity before earthquakes were surprising, and at first not at all credible:

> Researchers have come to understand that the triggering of electromagnetic forces that account for atmospheric conditions of storms, even the triggering of lightning, are grounding principles involving the electromagnetic fields of the earth, and not simply the aqueous and gaseous dynamics of the atmosphere itself. [KR]

> High degrees of positive ions in the atmosphere . . . a release of negative ions close to the ground. . . . When all of these reach a critical point, the final triggering of the quake [occurs from] the electromagnetic charge that has been built up. [KR]

> There is a general atmospheric disturbance involving highly charged air. [AAA]

> There is a combination of the forces within the earth itself . . . together with the electrical forces from the outside which are coming together and joining, even as you would see a discharge of energy between clouds. Here you have solid clouds. There will be an eruption when these two meet, an explosion. That is the mechanism of it, for the earth is charged and so are these forces. They are charges, particles of charged energy. [AA]

After 1980 rapid advances in atmospheric physics led to an improved understanding of atmospheric electricity and lightning generally, and various data began to indicate their connection with earthquakes in particular. After a brief and early speculation (Pierce 1976), it gradually became known that electric charge was accumulating in the lower atmosphere and modifying the normal electric field prior to many earthquakes. This charge was found to arise from the emission of Rn out of the surface of the ground (already recognized—see EQG below), which was ionizing the air, and from compressed or impacted rock which generates positive hole charge carriers that ionize air molecules in the lower atmosphere. Both pre-earthquake charge production mechanisms have now been verified from experiments in the laboratory, and observations of electric field increases before earthquakes have been verified in several sites around the world (e.g., Jianguo 1989, Ifantis, Tselentis, Varotsos, & Thanassoulas 1993, Varotsos, Sarlis, Lazaridou, & Kapiris 1998,[9] Varotsos, Hadjicontis, & Nowick 2001, Freund 2002, Takeuchi, Lau, & Freund 2005, Freund, Takeuchi, Lau, et al. 2007, Freund, Kulahci, Cyr, Ling, & Winnick 2009, Pulinets 2009).

Other factors as well are apparently at work. Close-to-the-ground air ionization is probably responsible for the luminous phenomena sometimes observed (EQL) (Atmospheric Electricity 2011, Orville 2009). Aerosols from the ground tend to amplify the ground-level field strength (e.g., Tributsch 1978, Pulinets, Alekseev, Legen'ka, & Khegai 1997, Pulinets, Boyarchuk, Hegai, Kim, & Lomonosov 2000, Sorokin, Yaschenko, Chmyrev, & Hayakawa 2006). Thunderstorms and other weather conditions play a part by moving charged water particles upward where conductance and temperature are higher, so that very high potentials (up to a gigavolt for a lightning strike) can build up.

It is still not known which of these production processes that increase the atmospheric electric field intensity is primary, and (at the moment) whether the charge accumulation is an integral part of the triggering process or is only ancillary to it. Still, there is now no doubt that electrical field increases in at least the lower atmosphere accompany many earthquakes and constitute a valid earthquake precursor.

This evidence validates the intuitive information on pre-earthquake electric fields. It also provides a mechanism that is consistent with the other atmospheric electrical phenomena mentioned above and discussed below—"earthquake lights" and St. Elmo's fire (EQL) and various weather effects (EQW)—and may explain them.

EQM—Electromagnetic Energies

Before 1980 the notion that electromagnetic energies in the atmosphere are significant before earthquakes was even weaker than for electric fields, which at least had the clue of luminescences and lightning. While the electric field effect is essentially static and moves fairly slowly, electromagnetism occurs at various frequencies and propagates as waves at the speed of light. The intuitives contradicted this mis-assumption about electromagnetic energies in the atmosphere before earthquakes:

> . . . the content [combination] of electromagnetic and vibrational energies upon the molecular level within the earth crust itself. . . . It is the combined forces of gaseous pressure, electromagnetic activity . . . movement . . . toward the outer surfaces of the tectonic plates, wherein there is the gaining of the highly charged magnetic and electromagnetic forces . . . directly related to the earth's electromagnetic energies . . . also the electromagnetic charges building up beneath the earth's surface. [KR]

> The earth energy is less than 50 kilohertz. . . . Ninety to ninety-five percent is electromagnetic, and yet there are other variations which also play a part in this. [LH]

> The main energy for earthquakes comes from the central core of the earth . . . is very powerful and can take any form . . . it has a very high vibration. . . . The electrostatic and electromagnetic forces act not directly on the epicenter, but in the surrounding area. [AA]

After 1980 the recognition that electromagnetic fields in the atmosphere were associated with earthquakes came from three sources: (1) ground-based and satellite measurements of electromagnetic energies of various frequencies (e.g., Gokhberg, Morgounov, Yoshino, & Tomizawa 1982, Larkina, Nalivayko, Gershenzon, Gokhberg, Liperovskiy, & Shalimov 1983, Parrot, Lefeuvre, Corcuff, & Godefroy 1985, Parrot 1990a, 1990b); (2) an accidental discovery of strong ULF signals in the area of the M7.1 Loma Prieta (California) earthquake of October 17, 1989 (the region was being monitored for another purpose)[10] (Fraser-Smith, Bernardi, McGill, Ladd, Helliwell, & Villard 1990, Campbell 2009); and (3) the recognition that stressed rocks can generate not only electrostatic but also electromagnetic radiation—essentially wideband noise over the range 10 Hz to 10 MHz (e.g., Warwick, Stoker, & Meyer 1982, Nitsan 1977, Martelli & Cerroni 1985, Ogawa, Oike, & Miura 1985, Cress, Brady, & Rowell 1987, Pulinets, Alekseev, Legen'ka, & Khegai 1997).

The first of these discoveries led to more than one hundred research reports on electromagnetic anomalies before earthquakes. They described magnetic and electromagnetic field measurements (nominally ELF,[11] usually taken as 0 to 300 Hz, through ULF from 300 Hz to 3 kHz, and a few reports for VLF at 3 to 30 kHz) near earthquakes in several parts of the world; laboratory tests on electromagnetic radiation from compressed rock, as just noted; postulated theoretical mechanisms as to where these signals are coming from, how they are being produced, and under what external conditions; and the detailed analysis and interpretation of observed data to ascertain which frequencies, how long before the shock, signal duration, signal quality, types of earthquakes, etc. (e.g, Parrot 1990b, Yoshino 1991, Park, Johnston, Madden, Morgan, & Morrison 1993, Stolorz & Dean 1996, V. Singh, B. Singh, Kumar, & Hayakawa 2006, D. Siingh, R. P. Singh, Kamra, Gupta, R. Singh, Gopalkrishnan, & A. Singh 2005, Hayakawa, Hattori, & Ohta 2007, Chauhan, O. Singh, Kushwah, V. Singh, & B. Singh 2009).

These various findings were not fully consistent, perhaps not surprisingly given the apparent complexity of the process. While the signals observed were often very strong, they were sometimes present without earthquakes and missing even for large quakes. Nor is it certain even today (2011) whether they participate in the triggering or are only indicators. They did show that electromagnetic energy is coming from both the ground and the ionosphere (or magnetosphere), and the signals are strongest and clearest near the epicenters and close in time to the largest earthquakes. The effect appears to be affected by weather conditions (storms, dryness, winds, etc.) and the depth of the fault, as already suspected for the electrostatic field alone. In short, the electromagnetic phenomenon emerges as atmospherically complex and subject to influential and interacting factors still not fully identified.

The second discovery inspired the creation of a private "QuakeFinder" network[12] of 60+ detectors of ULF signals and other candidate precursors, along with telemetering and analysis equipment (Bleier, Dunson, Maniscalco, Bryant, Bambery, & Freund 2009, The Quake-Finder Network). Some potentially useful data are emerging.

The third discovery lends support to a more refined and multifunctional hypothesis, still unproven, in which the electrostatic charge emission from the ground into the lower atmosphere contributes to the ground–ionosphere electric circuit across the large annular waveguide around the earth (e.g., Pulinets, Alekseev, Legen'ka, & Khegai 1997, Pulinets 2004, Kazimirovsky 2002, Freund, Lazarus, & Duma 2010, Sorokin, Ruzhin, Yaschenko, & Hayakawa 2011). This hypothesis is developed further in the next section.

While there is now no doubt that electromagnetic energies are playing an important role in earthquake triggering, it is not yet known for certain whether they constitute by themselves a distinct causative precursor (Parrot, Achache, Berthelier, Blanc, Deschamps, et al. 1993, Johnston 2002). The many observations and measurements verify the intuitives' broad statements, though a full understanding of the association is far from complete. Further intuitive inquiry would surely help answer these remaining questions.

EQI—Ionospheric Changes

Even more surprising were the intuitives' claims that the ionosphere, the multilayered curtain of charged particles (though electrons are dominant) located from 100 to 500 km above the earth's surface, undergoes measurable changes just before earthquakes and above their locations. It was almost inconceivable in 1980 how such a connection could exist, but the intuitives' descriptions were clear and fairly specific:

> [Describe these ionospheric changes that you mentioned.] In this case, there will be changes both in the pressure and in the particles themselves, such as there will be gases being changed from one state to another, or there will be a changing in the gases or pressures themselves. But as a whole, the ionosphere acts as a storage device, as a condenser, for the earthquake before it strikes. Lowered, it begins to release the energy, and then it rises again . . . within a few miles of the epicenter. It ascends as a balloon that has lost its baggage. There are changes taking place over a long period of time, but when the energy is released the changes take place very rapidly. [AA]

> [What parameters of the ionosphere are relevant here?] It has something to do with the lower layer. The height and density . . . vary, anyway. And it will be changes that you detect in this lower layer that will help to indicate it. [What kind of changes?] I see almost silver, like aluminum foil or that type of thing, as though the way it reflects seems to be the changing factor that indicates what the change is going to be. [LH]
>
> [The critical] focal point can be detected by an ionospheric disturbance, which will vary in size like a hole and travel over the atmospheric sheath like the shadow of the moon. You can detect it coming, and if it falls on a vulnerable spot, the earthquake occurs. [MA]
>
> [Does the ionospheric activity you mentioned affect the earth directly or only through the weather, when triggering an earthquake?] Only by the weather. It creates the atmospheric and electrical discharge that completes or causes other changes. . . . The heat and dryness of the earth's crust is . . . the final catalyst after the pressure buildup has reached a certain point . . . even though the particular time of the occurrence is not dry per se. . . . The dryness seems to cause an electrical spark. [LH]

Unusual ionospheric activity before earthquakes was first detected by radio-sounding stations just before the M6.3 Hawaii earthquake of April 26, 1973,[13] then by another before the M9.2 Alaska earthquake of March 27, 1964 (Davies & Baker 1965, Moore 1964, Leonard & Barnes 1965).[14] The spate of scientific satellites launched in the 1980s opened up a new era of space observation of the earth environment, including the ionosphere at various sites, latitudes, and times of day. Following the first report of earthquake–ionosphere coupling (Gokhberg, Pilipenko, & Pokhotelov 1983), several satellites now have the capacity to monitor ionospheric changes, and DEMETER, launched in 2004, was used exclusively for detecting pre-earthquake ionospheric variations (e.g., Lagoutte et al. 2006, Sarkar, Gwal, & Parrot 2007). In 2004 NASA inaugurated the Global Earth Satellite System (GESS), a "twenty-year program to enable earthquake prediction," using ionosphere measurements (EQI) as well as temperature (EQTh) and geodetic measurements, the magnetosphere (EQS), and other related earth-monitoring tasks from space (Solid Earth 2003).

These measurements, supplemented by others from ground-based VLF/LF radio transmissions, ionosphere-sounding stations, and geostationary GPS satellites, have shown conclusively that the Total Electron Content (TEC) of the ionosphere and the height of its lower E layer are frequently disturbed a few days before major earthquakes, and not excessively so at other times (e.g., Liperovsky, Pokhotelov, Liperovskaya, Parrot, Meister, & Alimov 2000, Liperovsky, Meister, Liperovskaya, Vasil'eva, & Alimov

2005, Chuo, Liu, Pulinets, & Chen 2002, Harrison, Aplin, & Rycroft 2010, Hayakawa, Kasahara, Nakamura, Hobara, Rozhnoi, Solovieva, & Molchanov 2010, Ouzounov, Pulinets, Alexey Romanov, Alexander Romanov, Tsybulya, Davidenko, Kafatos, & Taylor 2012).

The mechanism of this phenomenon is just beginning to be understood. It begins with the accumulation of atmospheric electric charge near the ground (EQE). This charge cloud rises up to the lowest level of the ionosphere, where it is amplified by the favorable conditions there and induces changes in the ionosphere's composition, pressure (electron density), and height. When strong enough, it can create a gap or hole, thereby reducing radio reflectivity (Sorokin, Yaschenko, & Hayakawa 2006). By participating in the global electric current back to the ground, it reacts downward as a kind of quiet lightning, possibly affecting the earth itself and helping to trigger an earthquake. Recent articles (Pulinets 2004, Gokhberg, Morgounov, & Pokhotelov 1995, Sorokin, Yaschenko, Chmyrev, & Hayakawa 2006, Freund 2007, Pulinets 2009) provide additional details on this overall hypothesis and speculate further on how the process might be taking place.

Unfortunately, local ionospheric behavior appears presently to be complex and erratic even under undisturbed conditions. Careful analysis will be required to relate the specific pre-earthquake variations to the specific location, type, timing, and size of the earthquakes (Siingh, R. P. Singh, Kamra, Gupta, R. Singh, Gopalkrishnan, & A. Singh 2005, Karatay, F. Arikan, & O. Arikan 2010, Astafyeva & Heki 2009, Liperovsky, Meister, Liperovskaya, Vasil'eva, & Alimov 2005); and to distinguish these meaningful signals from the ever-present noise and other effects, both known and unknown: daily (day and night) changes, solar-induced geomagnetic/magnetospheric storms (see EQS below), lightning, man-made radio transmissions, nuclear explosions, and disturbances from space shuttles and rocket launches (Hayakawa, Kasahara, Nakamura, Hobara, Rozhnoi, Solovieva, & Molchanov 2010). As of 2011, these intricate analyses are still in progress.

In any case the accumulated evidence for an ionospheric precursor is sound, and it provides positive hope for its eventual use as a short-term earthquake predictor if it can be sufficiently localized in time and to the epicentral area. The intuitive information on the ionospheric precursor is therefore verified. The "storage" phenomenon mentioned therein has not been specifically reported in connection with earthquakes, though it could reasonably be expected from present-day geophysical understanding of atmospheric and ionospheric dynamics. New research and further intuitive inquiries are called for.

Precursors Partially Verified by Intuitive Insights

EQTh—Thermal Effects

Before 1980 it was well known that the earth generates heat from its interior, more or less uniformly over its surface, but a little warmer below the oceans and above plumes and volcanoes, and a little cooler above plate boundaries. It is surprising that possible variations in this normal heat flow were never seriously investigated as a precursor. The intuitives were not hesitant to remind us of it, with comments such as:

> The centrifugal force of the earth's rotation causes movement of the magmas along the cooling crust, [producing] rarefied or heated forces from the expansion of these molten materials seeking release into the atmosphere. . . . [They] combine with the thermal expansionary forces of the molten masses beneath the surface to [cause] movement along the inner structures, toward the outer surfaces of the tectonic plates. [KR]

> The heat and dryness of the earth's crust is . . . the final catalyst after the pressure build-up has reached a certain point. [LH]

Recent infrared measurements from satellites have revealed increases in surface temperature up to 4°C one to two weeks before several major earthquakes, and a return to normal a few days afterward (e.g., Gorny, Salman, Tronin, & Shilin 1988, Saraf & Choudhury, 2005, Saraf, Rawat, Choudhury, & Das 2009, Ouzounov, Bryant, Logan, Pulinets, & Taylor 2006). In the absence of plausible mechanisms, however, these data are "hotly" contested.

It is nowadays well established that fissures, faults, mid-ocean ridges, and volcanoes provide for the upward convection of hot magma and the seepage of heated ground water. Convective transfer of this heat to the earth's surface, whether near earthquakes or not, is doubtful, however, because of the absence of clear heat transfer mechanisms and the large thermal inertia of intervening rock. If the satellite data turn out to be valid, another means of heat production may need to be found to explain them.

Fifty to 90% of the heat emanating from the earth is known to arise from the natural decay of the radioactive elements ^{235}U, ^{238}U, ^{232}Th, and ^{40}K, which exist in the crust and upper mantle but not at the high temperatures and pressures that prevail at greater depths (^{40}K may lie somewhat deeper). The balance of radiated heat is left over from the early formation of the earth, from the gradual sinking of the heaviest matter toward the core, the convection of soft magma upward, and the flexing of the earth due to lunar and solar tidal forces. All of these processes generate heat from gravitic compression or frictional movement (Tronin 2002, Guo 2008), but none is able to account for the relatively rapid temperature rise observed before earthquake shocks and the drop soon afterward (Earthquakes 2003).

Theories of an alternative source of heat are based upon laboratory tests of the compressed rock itself, which may produce heat directly (Saraf et al. 2009); theoretical claims that ionization in the atmosphere may generate heat directly (Pulinets 2004); the possibility that positive hole recombination from compressed rock generates heat (Saraf et al. 2009, Freund, Takeuchi, Lau, Al-Manaseer, Fu, Bryant, & Ouzounov 2007), or gas or electromagnetic emission affecting thermodynamic processes in the atmosphere (Krasikov 2001, Pulinets 2004). Which (if any) of these mechanisms of local heat production before earthquakes may be responsible is still unresolved.

There remains the task of determining if the heat anomaly is consistently present before earthquakes, identifying its specific source and local expression, and verifying the precursory timing.

The intuitives' recognition of the existence of a thermal precursor is partially verified. Because of the relative ease by which ground temperature may be measured from space, this precursor shows some promise as a contributor to future earthquake prediction.

EQL—Earthquake Lights

The intuitives cited near-earth atmospheric luminescence as a valid though inconsistent precursor. Since ancient times, such glows in the sky have been reported anecdotally near the locations and times of earthquakes, but scientifically acceptable data were lacking. (e.g., Terada 1931, Ulomov & Malashev 1971, Derr 1973, Hedervari 1981).

Post-1980 reports of such pre-earthquakes luminescences are more wide-spread and better documented (Corliss 2001, Derr 2005, Freund 2003, St. Laurent, Derr, & Freund 2006, Lockner, Johnston, & Byerlee 1983, Heraud & Lira 2011). They confirm that the phenomenon is a genuine precursor, but the data are still not consistent and reliable enough to indicate the size and type of earthquakes they accompany. Indeed, the "lights" occur without earthquakes, and large earthquakes occur without the lights.

The extensive pre-earthquake electrical activity in the atmosphere, already validated above (EQE), offers a ready explanation for such earthquake lights, which could have only an electrical or possibly an electrochemical origin. It appears unlikely that earth gases (EQG) are also participating in these luminous effects, though this possibility cannot be ruled out at present (King 1986).

Pre-earthquake atmospheric luminescence is therefore a valid precursor, just as the intuitives indicate, but it is too irregular to be useful by itself for prediction purposes. Nor is it likely to be helpful for studying the triggering process.

EQS—Solar Activity and the Geomagnetic Field

Might earthquakes be induced by solar activity? The intuitives imply that solar effects on the earth's geomagnetic field are indeed a causal part of the earthquake-triggering process, but it is difficult to imagine any such mechanism from known physical theory to support a claim of causality. The overall phenomenon is irregular and involves other factors as well, so it can be only contributory:

> Gravitational forces from both the planets and heavier activities [affect] the release of many radiations from the surface of the sun. All these activities indeed are integrated with the phenomena. [KR]

Leaving aside a planetary influence for the moment (see EQP below), sunspots and other purely visible solar features have long been recognized and recorded, but the internal plasmic activity did not become known until after satellite measurements began in about 1980. Solar activity is now understood to be generating the sunspots as well as solar flares, solar wind, and other strong radiations that propagate outward into the solar system, somewhat irregularly and at various speeds. These emanations create the magnetosphere that surrounds the earth, a modulation of the natural geomagnetic field and the earth's electromagnetic environment with ionospheric changes, aurora, and disrupted radio transmissions, to name a few effects (Merrill, McElhinney, & McFadden 1996). They are responsible for some climatic variations and may also influence the weather and the atmospheric electrical phenomena already discussed (EQE, EQM). Under favorable conditions they may conceivably participate in the triggering of earthquakes. So a possible chain of cause and effect exists for allowing solar activity to be an earthquake precursor. Its credibility rests most strongly on the unknown effect of atmospheric electromagnetic fields on the stressed fault itself.

Better evidence for this putative sequence comes from a direct association of measured geomagnetic activity (such as geomagnetic storms) with the record of prior earthquakes and perhaps volcanoes. The results of this comparison are unfortunately unclear: Attractive evidence has been found both for and against such a correlation (Johnston 1997, Duma & Ruzhin 2003, Eftaxias, Balasis, Papadimitriou, & Mandea 2009, Yesugey 2009), but neither argument is fully convincing.

One may also try to correlate solar activity directly with the historical record of earthquakes. The former is measured by the Sunspot (Wolf) Number (roughly, the total number of sunspots visible on a given day). The 300 years of records show a clear 11.1-year cycle, and an early comparison revealed a small increase in earthquakes during the minima of this cycle (Simpson 1967). Two recent studies agreed (Stothers 1989 [volcanoes] and Zhang 1998 [earthquakes]). The case is still being argued (Khain & Khalilov 2009, Casey 2010), and again the alleged correlation remains less than certain.

These tentative findings suggest that earthquakes are indeed related to sunspots and solar activity, through the geomagnetic field around the earth, but other still unknown factors also appear to be involved. The findings to date are weakly supportive of the intuitive statements but still not decisive. The issue remains open.

EQP—Planetary Effects

The intuitives cite the planets of the solar system as having an influence on earthquake triggering through their gravitational effect on solar activity and the resultant radiations which affect the earth. Again:

> Gravitational forces from both the planets and heavier activities [affect] the release of many radiations from the surface of the sun. All these activities indeed are integrated with the [triggering] phenomena. [KR]

Seismologists have left the possibility of planetary influences on earthquakes to astrologers, if they ever took the matter at all seriously, and astrologers have responded with at least a dozen speculations on critical planetary configurations and even specific predictions of their own. None of the articles published in the astrological literature have been able to meet scientific criteria for validity. Either the statistics were misapplied, the theory or prediction was not sufficiently specific to be tested, verification by the astrologers or others was never actually attempted, or the expected quake never occurred (Tomaschek 1959, Dean 1977, Phillipson 2000). A few scientists and technical writers have done their part, too, with no better success (Johnston 2002, Harnischmacher & Rawer 1981, Gribbin & Plagemann 1975).

Planetary science provides no plausible mechanism for a direct causal effect from the planets upon earthquakes. The gravitational force of all planets combined is much too weak to be directly effective on the earth—less than one ten billionth of that of sun. An indirect influence may be possible, however. The combined force of the heavier planets moves the center of mass of the solar system around inside the sun, and even outside of it as these bodies move in their orbits. Discoveries by Jose (1947) and Wood and Wood (1965) showed that sunspot occurrence is directly correlated with the rate of change of angular momentum of the sun about the center of mass of the solar system, which follows the 11.1-year cycle. This activity might then affect the convection of plasma inside the sun, influence the formation of sunspots, and modify the resultant radiations emitted by the sun, as described above (EQS). Since these radiated energies are known to distort the earth's geomagnetic field, the resultant near-earth storms may be involved as part of the earthquake-triggering process, as suggested in the previous section and as the intuitives say they do. Physical mechanisms have been proposed that would actually allow such an influence (Duma & Ruzhin 2003, Freund, Lazarus, & Duma 2010).

This long scenario would obviously have to be causal, not indicative. If it can be shown to be a valid precursor, it would allow at least some degree of predictability, simply because the motions of the planets are governed by fixed laws and their positions are perfectly predictable. Further research will be needed to complete the argument, for these effects must occur at just the right times, frequencies, intensities, and locales on the earth for the combined activity to be sufficient to trigger a local shock. Other less apparent factors may need to cooperate as well.

While this sequence from initial cause to final effect is partially speculative, and therefore not acceptable as a full explanation, the overall scenario is credible and partially supports the intuitives' claim. Their statements therefore stand as partially verified, the more so if the geomagnetic/magnetospheric influences (EQS) turn out to be valid and the electromagnetic fields can be shown to actually trigger the fault. This possibility merits further exploration. A study could benefit especially from additional intuitive inquiries.

EQT—Solid-Earth and Ocean Tides

> Earth tides aid the triggering process. [AAA]
>
> [Did you say tides in the crust of the earth?] They are responsible to a minor degree. [AA]
>
> The forces of gravity would be minor upon the earth's crust. The alignment of both the moon and the sun [may] . . . cause an upset in the earth's own ability to balance these forces electromagnetically. [KR]

It has long been known that the gravitational pulls of sun and moon cause a twice-daily heaving of the earth's crust by up to half a meter, and of the oceans up to two meters, as the regions of highest gravitational stress sweep over the earth's surface antipodally while the earth rotates beneath them. They peak at syzygy—the lineup of sun, earth, and moon—and when the moon is closest to the earth (perigee).[15] It is only natural to wonder if these forces, or possibly their spatial derivatives across the fault, might trigger already stressed portions on the verge of release. Amateur predictors are in their element with this one, since the forces are extraterrestrial and are at a maximum during the magic moment of eclipses.

One may readily check this candidate precursor by comparing the voluminous records of past earthquakes with the gravity forces from the sun and moon, which are readily calculated at the times and locations of each quake (e.g., Darwin 1962). Dozens of such studies have been carried out. Early findings were ambiguous, and some were in error due to neglecting the eccentricity of the moon's orbit (Cotton 1922, Simpson 1938, Tamrazyan 1967, Knopoff 1969, Shlien 1972, Mauk & Kienle 1973). Studies after 1980 revealed a definite but small and irregular triggering effect, just as the intuitives indicated (e.g., Bibliography: International Center for Earth Tides, Heaton 1982, Sue 2009, Zhao, Yanben, & Zhian 2000). The most recent of these revealed particular fault modes and areas under which the effects are most likely to occur, namely, when the earthquake is shallow, the tidal force lifts up the fault, or differential loading occurs across the fault from nearby ocean tides (Kilston & Knopoff 1983, Cochran, Vidale, & Tanaka 2004, Kansowa & Tatnall 2010, Tanaka 2010). The effect is not consistent, however, so it probably depends upon the particular state of the fault.

The intuitives' statements on the tidal precursor, obviously causal, are validated as stated, except for the comment about "electromagnetic balancing," which is unclear. The overall effect is probably too unreliable to make it useful by itself for prediction purposes.

EQG—Ground Gas Emission

> Toward the outer surfaces of the tectonic plates, wherein there is . . . the accumulation of both gaseous and aqueous forces, . . . the building of gaseous forces, observable within at least a 50 to 100 mile radius of the quake. . . . There will be radon, xenon, some . . . argon and also increases of hydrogen and oxygen . . . in proportion as normally found in the aqueous state of water. [KR]

Many gases that are emitted from the earth's soil, some continuously, have been tested for their sensitivity to earthquakes. Rn, CO_2, and CH_4 have shown the most significant co-seismic variations (King 1978, 1980, 1986, Voitov & Dobrovolsky 1994, Pulinets, Alekseev, Legen'ka, & Khegai 1997, Zhou et al. 2010). ^{222}Rn is produced naturally in the earth's crust from the radioactive decay of radium (^{226}Ra) which seeps to the surface along water channels and through microfractures, faults, and volcanic structures. With a half-life of only 3.8 days, it soon decays, but not before creating a health hazard to humans who are exposed to too much of it.

Rn has been observed in surface water and in deep wells since 1966 at several locations in the world and has been explored for its possible association with earthquakes (Ulomov & Malashev 1971, Teng 1980, C. King, B. King, Evans, & Wei 1996, Igarashi, Saeki, Takahata, Sumikawa, Tasaka, Sasaki, Takahashi, & Sano 1995, Singh, Kumar, Zlotnicki, & Kafatos 2010). Its detection is not difficult, and measurements taken along known faults have shown large increases just before many major shocks. Reliable ongoing monitoring has proven difficult, however, because rainy weather, natural soil moisture, varying soil chemistry, and changing hydrologic conditions interfere with accurate measurement. The most recent attempts are encouraging but still not sufficiently uniform and consistent to provide reliable precursory information that might be useful for predictive purposes, even in well-monitored seismic areas. Moreover, it is still not clear if the increases in Rn concentration before earthquakes occur for all major events or if they also occur in non-seismic circumstances. And are they merely indicative of impending earthquakes or a prime contributing cause? The results from EQE suggest the latter.

Inflammable earth gases (CH_4, CO, and H_2) have also been proposed as an earthquake precursor (Wakita, Nakamura, Kita, Fujii, & Notsu 1980, Gold 1994, Singh, A. Kumar, Bajwa, Mahajan, V. Kumar, & Dhar 2010, Jones 2002). The intuitives agree. For example:

> Metal deposits within the earth are concentrated in certain peculiar shapes and forms. When gases of a certain nature reach these they create an explosive effect that causes changes to come about. Now this . . . is a definite factor in some areas. [LH]

These gases are already known to accumulate in coal mines, where they have led to damaging explosions. They can also arise from ruptured gas lines, underground gas storage cavities, and seepage from natural gas wells. If ignited in seismic areas, such explosions could certainly induce slippage along faults. It may be difficult to detect them simultaneously with the quake unless they are large and close to the surface. There are no observational data that identify such natural gas explosions as the cause of an earthquake, though underground nuclear explosions are known to be capable of doing so.[16] The intuitive statement is therefore plausible, though it may not be relevant to a gas-related precursor.

While the intuitives' information on ground gases is broadly confirmed, more research will be necessary before the detection of Rn or other soil gases can be confirmed as a useful indicator or cause of triggering action, and especially as a useful precursor. Further intuitive inquiry could help to answer these questions.

EQF—Centrifugal Forces Inside the Earth

It has long been known that centrifugal forces, arising from the earth's steady rotation upon its axis, induce complex circulations in the plastic magma layer in the mantle. These motions are suspected of being responsible for driving the tectonic plates in their slow movement on the upper mantle and contributing thereby to earthquakes at a basic, global level (Lay & Wallace 1995). The intuitives confirm this suspicion and go on to explain further. One of them puts it this way:

> There are two forces which would account for triggering the final activities of quakes. The centrifugal force of the earth's rotation causes movement of the magmas. . . . In the centermost [portion] of tectonic plates the centrifugal force of the planet in its axis of rotation combines with the thermal expansionary forces of the molten masses beneath the surface to [cause] movement along the inner structures, toward the outer surfaces of the tectonic plates. . . . The pressures of centrifugal forces combine with the normal expansionary pressures of any heated matter. When all of these reach a critical point, the final triggering of the quake [takes place]. . . .
>
> When there is a concentration of the plasmic field, when it becomes exposed to the earth's magnetic field plus the earth's centrifugal force, [then there] is this critical force that causes a transference of energy from the kinetic level to the molecular level of the earth's stable crust. This is the setting-off factor that, in its own right, actually triggers the quake. [KR]

The claim for a role by the earth's static magnetic field (0.3–0.6 gauss at the surface, ~0.25 gauss at depth) is not presently seen as a contributing force in plate tectonics or lithosphere movement but only as an incidental consequence of the circular dynamo-like electric currents produced by convection in the earth's outer core, which consists mostly of molten iron.[17] These currents have a small retarding effect on the convection, thus upon the currents themselves, so the intuitive's statement is technically correct. But this is probably not what he meant.

Rather, his statement seems to be referring to magnetic forces large enough to assist the movement of magma upward to become a "molecular" (solid) triggering force in the crust, perhaps similar to the plume under a volcano. Accepted plate tectonics offers no support for such movement beneath earthquakes except along plate boundaries. An alternative theory independent of plate tectonics proposes that other plumes, more widely spread, extend from the core to the crust and are influential not just for volcanoes but for earthquakes outside of plate boundaries (Morgan 1972, Foulger 2010). These plumes would be very hot, thus detectable by satellite (EQTh). This hypothesis remains to be confirmed for both volcanoes and earthquakes.

The intuitive description is therefore verified except for this last point, and again for the specific role of the earth's magnetic field as a regional triggering force. More data are required on the physical role of the earth's magnetism at the level of the magma, and especially how the centrifugal motion in the liquid core and mantle could induce regional seismicity.

EQW—Earthquake Weather

Weather changes are popularly believed to be indicators of forthcoming earthquakes (and numerous other unexplained events)—a muggy feeling in the air, strange winds, heavy storms, unusual cloud formations, etc.—but this widespread and enduring legend lacks adequate data to qualify it as a genuine precursor. Even if the data were valid, such changes are not sufficiently unique and consistent to signal a shock reliably.

There is some basis for accepting such influences as causal but only if they are indirect—that is, causal of intermediate phenomena which then induce the earthquakes. Numerous reports after 1980 speak of heavy rainfall saturating the ground (Costain & Bollinger 2010, Schultz, Kean, & Wang 2009); typhoons, which have initiated small earthquakes in Taiwan, presumably from the sudden drop in air pressure (Liu, Linde, & Selwyn Sacks 2009); and hurricanes and flooding that can trigger landslides and avalanches under certain conditions and may participate in triggering earthquakes as well (Larsen 1990, Schultz, Kean, & Wang 2009, Wdowinski, Tsukanov, Hong, & Amelung 2011).

The intuitives agree with some of these speculations and associated precursory mechanisms; for example:

> There is often the attraction of certain cloud forms to areas of quakes, and even the stilling of the atmosphere. . . . observable cloud structures, bulbulous [bulbous?] and towering in nature, up to 50 to 200 miles from the center . . . a great release of quantities of water from the atmosphere. [KR]
>
> The heat and dryness of the earth's crust is … the final catalyst after the pressure buildup has reached a certain point … even though the particular time of the occurrence is not dry per se. [LH]

Large cumulus and other unusual cloud patterns before particular shocks have often been reported from Japan and China (e.g., Wu, Li, & Liu 2009, Dicks 2008, Guo & Wang 2008), and the dryness of the crust is consistent with the favorable pre-earthquake atmospheric conditions involving electric charge buildup (EQE) and electromagnetic activity (EQM) (F. Freund, Kulahci, Cyr, Ling, Winnick, Tregloan-Reed, & M. Freund 2009). Moreover, the weather itself is now seen to be a dynamic electromagnetic process, interactive with familiar atmospheric thermodynamics:

> Electromagnetic forces that account for atmospheric conditions of storms, even the triggering of lightning, are grounding principles involving the electromagnetic fields of the earth. They are . . . directly related to the earth's electromagnetic energies. [KR]

During the 1980s, satellite observations allowed the earth's weather to be monitored from space, and large computers enabled it to be modeled and forecast globally and accurately. Electromagnetic effects such as lightning, auroras, and the movements of ionospheric layers began to be better understood. The overall process turned out to be very complicated. There is much to be explained before the full relationship between earthquakes and the weather can be understood, even just looking for a practical precursor.

The intuitives' comments on weather phenomena associated with earthquakes are simple but partially supported by the knowledge and data gained in the last thirty years. While none of the information has been contradicted, most of it remains to be verified. At this point weather changes may become a contributing precursor, but their great variability makes it doubtful that they will turn out to be very useful as such.

EQA—Abnormal Animal Behavior

Many animals are known to possess physical senses not enjoyed by humans, both in kind and sensitivity: sounds, vibrations, thermal radiation, gases (smells), electromagnetic and magnetic fields, and surely others (Buskirk, Frohlich, & Latham 1981). It is reasonable to expect that they may be able to pick up subtle environmental clues related to forthcoming earthquakes. Hundreds of popular reports of observations of abnormal animal behavior near particular earthquakes have come from all across the world, from ancient Greece to news items every year in this century. A persistent folk legend had grown up around the possibility. Reports of observations accumulated up to 1980 left no doubt that the phenomenon has at least limited validity as a precursor (Lee, Ando, & Kautz 1976, Evernden 1976, Davis 1979, Kerr 1980, Lott, Hart, & Howell 1981), though solid data were missing. While the intuitives confirmed this hypothesis, specifics were neither offered nor requested as to which kinds of quakes, animals, animal sensitivities, and perhaps other factors are behind the precursor.

Three surveys in later years sought to sort out the huge volume of accounts and try to identity those which were credible enough for scientific acceptance (Schaal 1988, Kirschvink 2000, Bhargava, Katiyar, Sharma, & Pradhan 2009). The main difficulty was that many of the reports arose only after the quake occurred and were therefore likely to be fortuitous recollections. Often the abnormal behavior itself occurred only after the quake. Most critical, they did not always distinguish the alleged abnormal behavior from ordinary animal behavior due to predators, rutting, storms, and fire sirens, for instance. Further research identified likely animal sensitivities (Buskirk, Frohlich, & Latham 1981) and explored some of the possibilities (Otis & Kautz 1981, Brown & Sheldrake 1997, Pararas-Carayannis no date) but led to no significant new options. See a recent report (Grant, Halliday, Balderer, Leuenberger, Newcomer, Cyr, & Freund 2011) on an indirect precursory possibility: toxic ground water.

The relatively few acceptable reports showed that the animal precursor is generally and widely valid though they revealed no useful pattern. There are just too many kinds of animals, earthquakes, and potential sensitivities to allow conclusions to be drawn about the underlying triggering process, let alone to serve as a useful precursor for prediction purposes. A major research effort would be needed to explore these many distinctions, and there would be no prior guarantee of eventual success.

The intuitives' information on abnormal animal behavior before earthquakes is therefore verified, though this precursor is not likely to be helpful by itself unless much research is carried out. Further intuitive inquiries could identify likely possibilities.

Candidate Precursors Not Verified

EQN—Nuclear and Other Radiation

Two intuitives spoke briefly of nuclear activity and radiation emitted inside the earth:

> [What kind of forces are acting upon the rock at the point of fracture or sliding?] These are static pressures that come about from electrostatic, electromagnetic, and nuclear pressures. The electrostatic and electromagnetic forces act not directly on the epicenter [hypocenter?], but in the surrounding area, while the nuclear force acts directly on the epicenter. [AA]

> The principal triggering action is coming from changes in the internal radiation which originates in the central core of the earth. … It throbs and pulsates like a powerful human heart, and is continually changing its shape. These changes affect its radiation accordingly. [BR]

> The main energy for earthquakes comes from the central core of the earth. This energy is very powerful and can take any form. … This energy has a very high vibration. . . . [It] is like atomic energy, and has some electrical and magnetic properties. [AA]

The term *radiation* is ambiguous since it can refer to any form of energy that is radiated, including thermal and electromagnetic waves as well as particle emission from nuclear decay. The “nuclear pressure” and “nuclear force” in the first excerpt may refer only to the radioactive decay in the crust and upper mantle which produces radon, as verified earlier for that precursor (EQG). The internal radiation in the earth’s central core (second excerpt) may be thermal only (EQTh). The vague terms *very high vibration* and *like atomic energy* (in the third) could also refer to thermal radiation. While these ambiguous intuitive statements have at least one valid interpretation, they are unfortunately not sufficiently informative to be verifiable.

Recent studies of anti-neutrinos emitted continuously from the earth have been helpful in determining its internal composition and source of heat emission. It is not yet known if the location and intensity of the anti-neutrinos are related to earthquakes in any way (except possibly for monitoring global heat generation [EQTh]), though the immense complexity and cost of the detection equipment (KamLAND and Borexino) precludes its use as a practical precursor that could be monitored regionally (Araki et al. 2005, Fields & Hochmuth 2006, Fiorentini, Lissia, & Mantovani 2007, Bellini et al. 2010).

Ionizing cosmic radiation is certainly impinging upon the geomagnetic field and ionosphere, parallel to the solar radiations already discussed (EQS), and could be playing a part in the ionospheric disturbances already verified (EQI) (Dorman 2004). The cosmic ray index has been found to be correlated with cloud formation at low altitudes, and the earth’s climate generally, though the claim has been contested (Svensmark, Bondo, & Svensmark 2009, Damon & Laut 2004). This influence was not mentioned by the intuitives except for a brief referral to an “upper energy” that affects the ionosphere. It could then be translated into infrared and propagated downward into the atmosphere. This phenomenon could be interpreted as cosmic radiation, but evidence is again lacking. The intuitives’ statements on nuclear and other radiation are unverifiable.

EQH: Human Precursors?

Since expert intuitives are able to provide detailed technical information on the earthquake-triggering process, might they also be able to predict earthquakes directly—that is, to be precursors themselves?

The answer is yes, but there are further conditions on this particular application of intuition because the prediction now becomes part of the event being predicted. Personal experience in collecting and evaluating intuitive earthquake predictions from both amateurs and experts shows that their efforts are sometimes remarkably successful, though their overall reliability and usefulness is small. It turned out that the intuitive acquisition of predictive information (of any sort) is easily limited or blocked unless the consequences of acquiring and utilizing it later are taken into account and respected. When the prediction would do more harm than good, because of consequences not foreseen, the flow of information can be blocked.

The expert intuitives offered further explanation for this blockage. First of all, they remind us that man already possesses both the intuitive and the physical capacities to be aware of when and where earthquakes are about to occur, and he is always free to make use of these faculties for his own benefit:

> Unconscious material is admitted into consciousness according to the beliefs an individual holds about himself, his reality and his place in it. Those who want to use their own unconscious precognition of such an event will take advantage of it. . . . On other than conscious levels, simply as creatures, you are well aware of impending storms, floods, tornadoes, earthquakes and so forth. There are many hints and signs picked up by the body itself—alterations in air pressure, magnetic orientation, minute electrical differentiations of which the skin itself is aware. [JR][18,19]

In other words, blockage is already taking place for almost everyone.

When intuitive earthquake predictions are intended for non-personal use, the reaction to the information is part of the prediction. Intuition can aid or retard the reception process. Since predictions for public use are not consistently accepted and acted upon equally by everyone, they can easily induce confusion and panic. To be useful they must be announced officially with scientific and governmental authority and with clear directions for evasive action, as noted earlier. Without this sanction, it is better not to release the prediction in the first place, or even seek it. A competent intuitive may not be able or willing to provide it (Kautz 2005).

For personal predictions, the intuitive process operates differently. The recipient is then free and responsible to choose whom he listens to and his own response. While the prediction can activate his fears and expectations, he is the only one who must deal with it. If he is the intuitive himself, he may find the information blocked. Even the most expert intuitives sometimes find it difficult to obtain reliable information about themselves. Like surgeons and psychiatrists, they know they can be blinded to their own issues and limitations.

Sometimes a prediction is not called for at all:

> Natural disasters are brought about more at an emotional level than at a belief level, though beliefs have an important part to play for they generate the emotions. . . . Those in earthquake regions are attracted to such spots because of their innate understanding of the relationship between exterior circumstances and their own private mental and emotional patterns. [JR][20]

That is, while one person will chose to live in a quiet locale which places few demands on his personal development, another will choose to live in an energetic environment with political unrest, wars, tornadoes—or earthquakes. Our private tremors tend to coincide with those of the earth! Persons inwardly seeking quiet and security will avoid such circumstances, while those seeking challenging drama will find themselves unconsciously gathering in earthquake-prone areas. This is just as some persons choose to join the military, enter the business world, or become involved in politics: They select what they deeply feel they need.

These individual choices can even help bring about the earthquake in the first place:

> The qualities of such individuals . . . en masse affect the deep electromagnetic energy of the earth. . . . Obviously, there have been earthquakes where there are no people, but in all cases the origins are to be found in mental properties rather than exterior ones. . . . Your feelings have electromagnetic properties. . . . There are what I am going to call "ghost chemicals"—aspects of normal chemicals that you have not perceived so far—which are changed into purely electromagnetic properties. Energy is released that directly affects the atmosphere. [JR]

Geoscience is not yet aware of any such "ghost chemicals."

Finally, and in a broader sense, man "creates" his earthquake experiences whenever he builds flimsy houses on ground susceptible to shaking, liquefaction, and slides, and constructs tall buildings covered with plate glass. He locates his cities (and nuclear reactors!) on shorelines subject to tsunamis. It is already established that quakes can be triggered from the creation of coal mines (Lovett 2010), dams and reservoirs (Gupta 2002), and geyser plants (Streepy 1996). It is also known that under favorable conditions small shocks can be turned on and off by pumping water into and out of wells near faults (Raleigh, Healy, & Bredehoeft 1976). Man explodes nuclear bombs underground (McEwan 1988) and extracts huge quantities of oil and gas out of the earth's crust (Bibliography, no date), without serious concern for how these activities might affect stressed faults. As new precursors are found, still more human effects on earthquakes may be uncovered.

Humans, aware or not, are creating many of their own earthquakes.

Conclusions and Implications

The past thirty years have seen the small, retiring subfield of seismology expand into its parent field of geophysics, thanks mainly to the wave of technological advances in space exploration and computation, and the global media awareness of costly and tragic earthquakes which has been enabled by modern global communications. At the same time the sheer complexity of the short-term earthquake prediction/forecasting problem has exceeded all earlier expectations and is now on the same scale as the problem of understanding the cause and treatment of cancer within the human body: much intricacy, no identifiable primary cause, many strongly interdependent factors, an interdisciplinary approach required (which the last generation of researchers are not equipped to handle), and no good clues on which of several possible approaches will most likely lead to a solution.

The most recent discoveries on the critical role of electrical activity (of many sorts) in the atmosphere and near-earth space, as anticipated by the intuitives thirty years ago, are adding their own fuel to this scientific explosion. They have contributed new portals for exploration, a deeper understanding of triggering, and several new precursors, but have not (yet) provided the specific directional clues that are so much needed now. Future intuitive inquiries hold this potential. The practical goal of short-term prediction still lies in the future, perhaps a distant one, and we are not even sure at this point if it can ever be reached.

Despite this complexity and expansion, we have learned that electrical activity in the ground, atmosphere, and space can no longer be neglected as part of the triggering process; that no one precursor is likely to be found sufficient by itself as measurable and reliable for short-term prediction; and that space exploration will continue to play a strong role in understanding the triggering process itself and which of the thirty or so potential precursors might be employed as measurable indicators for prediction purposes. Interested and experienced seismologists may be able to glean additional ideas from this article from the intuitive excerpts presented herein.

Nevertheless, the main issue in this paper was not seismology, despite its great interest and human importance, but rather the validation of a different and more powerful way of acquiring totally new information that can then be applied to any area, even outside of science, that is limited by a lack of relevant knowledge and understanding. This study has demonstrated, through an important example, that detailed, significant, and totally new knowledge may be obtained through suitably executed intuitive inquiry. By relying more heavily on intuitive methods in the future, the gateway to scientific discovery can be expanded widely. Examples taken from prior research in other disciplines apart from seismology suggest that there are few if any limits on the depth and breadth of knowledge attainable by intuitive methods (Kautz 2005, Grof & Kautz 2010) so long as appropriate questions can be asked and the inquiry has a positive human purpose. A rich reservoir is waiting to be tapped.

Notes

1 For example, the large annual meetings of the Association for the Study of Consciousness at the University of Arizona, now in their eighteenth year.

2 The hypocenter of an earthquake is the point within the earth where the rupture or slippage first begins; the epicenter is an imaginary point on the earth's surface, directly above the hypocenter. The region of strongest ground shaking may be neither of these, since it may arise from another portion of the same fault and depends in a complex way upon rock structures in the surrounding area.

3 The Japanese high-speed trains (*shinkansen*) operate at 210 km/hr, and are slowed to 70 km/hr after a very-short-term earthquake warning.

4 Let it be understood that the term *precursor* refers only to an advance signal or indicator that an earthquake is about to be triggered, or has been triggered. It need not be causal to the trigger, though in the investigation of the triggering process a candidate precursor should always be checked for a possible causal role.

5 Tape and transcript records are in storage in Sebastopol, California, USA. A preliminary report on intuitive inquiries on the earthquake-triggering problem appeared in *Psi Research* (Kautz 1982), a small journal no longer published, and a fuller report in Chapter 7 of the book *Opening the Inner Eye* (Kautz 2005).

6 Earthquake prediction research was effectively stopped in 1990 through legislation, promoted by Vice-President Al Gore, in favor of mitigation efforts. It has since been picked up again by several NASA projects centered around space observation, but there are no current (2011) USGS projects on prediction. Foreign programs on earthquake prediction in Russia, China, and Japan, with smaller programs in Greece, Turkey, and Italy, have bloomed in the last twenty years.

7 The reference to *electromagnetism* requires elaboration, for these forces include in their definition all known forms of radiation, from radio, infrared, light, ultraviolet, X-ray, and microwaves, to cosmic rays and even the fundamental particles of physics, which have both particle and wave properties. The distinguishing feature of all these forms of

energy is their wavelength (equivalently their frequency), which varies from many miles down to billionths of a millimeter and beyond. Static electricity and magnetism have zero frequency.

8 The bracketed initials [XX] indicate the contributing intuitives, who are more fully identified in the Acknowledgments.

9 The earthquake prediction claims made by this group ("VAN") have been severely criticized (Lighthill 1996, Kagan 1997), but the instrumental measurements ("SES") have not been questioned.

10 A later analysis (Campbell 2009) showed that the ULF signals were actually prevalent over much of Western North America at the time of the quake, not just near the epicenter. Fraser-Smith's claim for a ULF precursor is therefore weakened but could still be valid with the precursor active over a much larger area.

11 The electric and magnetic components are effectively independent at these low frequencies and must be measured separately.

12 Not to be confused with the Quakefinder system of JPL (Jet Propulsion Laboratory), which seeks to automatically and accurately map regional ground displacements as measured by satellite (Stolorz & Dean 1996).

13 Newspaper report from Honolulu, April 1973, no longer retrievable.

14 This phenomena must be distinguished from acoustic gravity waves created directly from the earth's vertical movement *during* the earthquake.

15 The term *syzygy* may refer to either an exact lineup of three planetary bodies, or merely a near lineup such as occurs at eclipses.

16 See, for example, http://en.wikipedia.org/wiki/Underground_nuclear_testing

17 Paleomagnetic traces near seafloor spreading played a major part in the development of the continental drift theory, now well accepted, though the earth's magnetism is not seen as driving the spreading.

18 Roberts 1972.

19 Roberts 1972.

20 Roberts 1972.

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