

HISTORY OF AN ISSUE: UPWELLING OF WATER AT YUCCA MOUNTAIN

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with technical input review and comment by concerned scientists

Nature of the Controversy

Several scientists originally associated in various capacities with the effort to evaluate the suitability of the Yucca Mountain site as a proposed repository for high-level radioactive waste and spent reactor fuel have participated in ongoing investigations of a potentially "show stopper" issue which has become known as the **hydrothermal upwelling of water** issue. These scientists will be referred to herein as the "concerned scientists." They include Jerry Szymanski, Dr. Yuri Dublyansky and his colleagues at the United Institute of Geology, Geophysics and Mineralogy, Siberian Branch of the Russian Academy of Sciences, in Novosibirsk, Russia, Dr. Tim Harper in England as well as other scientists in the United States. Dr. Charles Archambeau of Boulder, Colorado was an active participant until more pressing personal concerns caused him to assume an advisory role.

The concerned scientists have pursued the hypothesis of the upward movement of groundwater to the surface of Yucca Mountain first advanced by Jerry Szymanski. Szymanski developed a "conceptual model" to explain how and why the upwelling of water has episodically occurred in the past at Yucca Mountain. Szymanski proposed that the rapid ejection of water contained in pores and fractures in deep seated rocks during their complete or partial closure in response to an earthquake ("seismic pumping") was responsible for the abundant calcite-opal deposits found in veins in and around Yucca Mountain. He further proposed that episodic convective flows of hot groundwater could be caused by the continued heating of the Earth's crust by a mantle mound underlying the crust in the vicinity of Yucca Mountain. Szymanski hypothesized that after either or both of these natural processes had been initiated, a pumping phenomenon caused by carbon dioxide effervescing out of solution increased the velocity and energy of the upward surging water along faults and fractures. After the energy dissipated, the water deposited calcite and opal, as well as a variety of other secondary minerals (e.g. quartz, chalcedony, fluorite, heulandite, etc.), commonly observed at the surface and in the faults, fractures and cavities (e.g. lithophysae) in the subsurface of Yucca Mountain where the proposed repository is planned.

The U.S. Department of Energy (DOE) and the U.S. Geological Survey (USGS) scientists recognized the extreme significance of this issue and, in response, argued that while the physical processes described by Szymanski have been observed or inferred in other locations in the world, there is no “believable” evidence that they were active in the recent geologic past at or near Yucca Mountain. Instead they argued and still maintain that most of the data and observations involving secondary minerals such as the calcite-opal veins can be explained as resulting from deposition by infiltrating rainwater descending downward from the surface along pathways provided by the faults and fractures in the sequence of tuff deposits that make up the mountain.

During their investigations the concerned scientists have reached a number of firm conclusions concerning the nature and origin of the calcite/opal deposits ubiquitous to the Yucca Mountain environs, which are at odds with the evaluation of the same deposits by the DOE and USGS scientists. Both groups recognize that the proposed high-level nuclear waste repository site at Yucca Mountain is located in a tectonically-active area of volcanism, faulting, and earthquake activity. They agree that the calcite/opal deposits found in the vicinity of the Mountain and deep within it at the proposed repository horizon are an integral part of the regional geologic scene. The nearly universal association of calcite/opal deposits, exposed at the land surface, with faults, and the vein geometry displayed by these deposits originally suggested to the concerned scientists that such deposits must be associated with an epithermal, hypogene origin of the depositional fluids, the crux of the upwelling issue. However, the view developed and espoused by the DOE and USGS is that they are the product of infiltrating rainwater, a pedogenic, supergene origin. Thus, the issue has also been referred to as the hypogene-pedogenic controversy.

The question of the origin of the fluids responsible for the deposition of the calcite-opal deposits developed into a hotly contested issue without appropriate resolution in the opinion of the concerned scientists. The controversy over the origin of the deposits has become sharply focused by the existence of an extensive set of scientific factual data. A large set of geochemical, mineralogic, fluid inclusion, geochronologic, and isotopic data has been assembled to form a coherent picture of episodic invasions of the vadose zone by epithermal fluids. The data show that these invasions occurred intermittently during the Plio-Quaternary time span and are recorded through a paragenetic assemblage consisting of three chemically and isotopically compatible elements. These are: a) metasomatic alteration, b) calcic zeolitization, and c) carbonatization. A number of lines of evidence all point to the same internally consistent conclusion: the controversial calcite/opal deposits at Yucca Mountain are of hypogene origin. The DOE/USGS group has chosen to ignore critical data and to emphasize data that is, at best, equivocal in their effort to rationalize their pedogenic origin hypothesis. As the data became more certain they have repeatedly resorted to transparently contrived fixes to explain data that contradicted their hypotheses. More than once the lines of research which hold promise in resolving the controversy were abandoned after the first results turned inconsistent with the preferred pedogenic model. Their failed efforts in this regard are evident from the history of the issue.

An important set of data was compiled as the result of early fluid inclusion studies conducted by Dr. Yuri Dublyansky and his colleagues at the Institute of Mineralogy and Petrography, Siberian Branch of the Russian Academy of Sciences, while representing the State of Nevada. These scientists found small gas and fluid filled inclusions (small voids) within crystals of calcite that had formed from depositional processes. These "two phase inclusions" were used to determine the temperature of the fluid at the time of its entrapment in the crystals. Dr. Dublyansky with his colleagues reported the presence of two-phase fluid inclusions indicating depositional temperatures of up to 85°C, as well as gas-rich inclusions containing methane as the dominant gaseous phase. They concluded, based on the data, that the minerals were deposited from deep seated hydrothermal fluids. The DOE/USGS group of scientists reported a finding based on their early and, as realized later, their technically deficient fluid inclusion studies, that only all-liquid inclusions are present in the secondary minerals and that they were likely deposited from ambient temperature fluids and proposed their model of water from meteoric precipitation percolating downward through several hundred meters of the vadose zone. It was the implications for the safety and anticipated performance of the proposed future repository that prompted the Nuclear Waste Technical Review Board in 1998 to recommend and the DOE to commission a verification study, which was eventually conducted at the University of Nevada at Las Vegas (UNLV). The plan was to set up an experimental program to systematically perform fluid inclusion temperature measurements and age dating of the calcite-opal deposits found in DOE's newly constructed exploratory tunnel.

The results of the UNLV Thermochronology Project were first released at the Geological Society of America meeting at Reno, Nevada on November 14, 2000. UNLV investigators, Drs. Jean Cline and Nick Wilson, reported the conclusion that across the repository site there is a record of hot waters averaging about 45 to 60°C. In their abstract they reported that "*Secondary minerals in the unsaturated zone at the Yucca Mountain site contain 2-phase fluid inclusions that recorded the passage of fluids with elevated temperatures.*" They also reported that the two-phase fluid inclusions were trapped more than 1.9 million years ago, some fluid inclusions were trapped more than 5.3 million years ago and some with temperatures between 35 and 41°C were trapped less than 5.7 million years ago. Notwithstanding these findings, the UNLV investigators embraced the DOE/USGS supergene model of deposition of secondary minerals.

The concerned scientists that attended the Reno meeting were aware of the results of the UNLV investigations because Dr. Yuri Dublyansky was the State of Nevada's representative for the Project, but the scientists were surprised and did not agree with some of the conclusions, which had been drawn by Cline and Wilson. These differences of opinion have fueled the debate to the present. The factual data appeared to be of exceptional quality but evaluation of the data remains controversial.

Because the DOE/USGS proposed supergene model of water from meteoric precipitation percolating downward through the mountain was inconsistent with the elevated depositional temperatures first reported by Dr. Dublyansky and his colleagues and subsequently confirmed by the

UNLV Project, the USGS modified their model so that it would be in rough agreement with the depositional temperature and ages. They hypothesized that a large volume of magma in a chamber beneath the Timber Mountain caldera some 7-9 kilometers to the north of Yucca Mountain must have remained hot and transferred heat energy to Yucca Mountain for millions of years after the Timber Mountain eruption some 12 million years ago. This they reasoned would explain why rainwater seeping downward through the tuff sequence could reach the elevated temperatures produced by the study with relatively young ages in relation to the 12 million year old eruption at Timber Mountain. To bolster their reasoning they attempted to prove it possible by computer modeling. The modeling performed in 2001 proved the heat transfer in this manner was insufficient to produce the elevated temperatures but the USGS scientists did not disclose the modeling results. Rather they continued to espouse the "hot mountain" hypothesis for years. In 2004, a DOE contractor, Bechtel SAIC, in response to a request by the Nuclear Regulatory Commission (NRC) staff made public the facts hidden by the USGS scientists. The NRC staff concluded that heat transfer from a magma source beneath the Timber Mountain caldera was not adequate to explain the elevated temperatures that accompanied the deposition of the secondary minerals. Unfortunately after rejecting the heat transfer hypothesis, the NRC staff selected an alternate explanation proffered by Bechtel SAIC that hot water must have migrated from the Timber Mountain location to Yucca Mountain during the relevant time periods. Research regarding the lateral outflow of thermal water toward Yucca Mountain was conducted by Bish and Aronson, scientists at Los Alamos National Laboratory (LANL), and reported in a journal paper in 1993. The LANL researchers documented thermal flow 10.5 million years ago but noted that such flow was limited to the saturated zone and not the unsaturated zone where the depositional processes took place. Their findings were ignored by both the NRC staff and Bechtel SAIC. As a consequence of the NRC staff's unfortunate cursory resolution of the issue, no further research will be deemed necessary prior to the licensing proceeding. Whether or not these events and the issue they affect will be aired in the licensing proceeding remains to be seen. The appropriate action would be to reverse the course of events and directly address and resolve the issue before the licensing proceeding. Failure to do so would be at odds with the congressional plan set forth in the Nuclear Waste Policy Act of 1982 (NWPA) to establish a repository "*...that will provide a reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository.*" 42 U.S.C. §10131 (1).

Significance of the Controversy

It is evident that there are major differences in the models proposed for the depositional processes operating at Yucca Mountain and they pose very different implications for repository performance and safety. Implications resulting from the supergene-hypogene controversy are far reaching, particularly with regard to: 1) assessments of the past and future behavior of the geologic

system operating at Yucca Mountain, and 2) assessments of the long-term performance of the proposed facility. In this regard, under the DOE/USGS supergene viewpoint it is predicted that water will infiltrate the repository from above the disposal facility. In this case the DOE expects the natural and engineered barriers to retain whatever integrity the DOE can reasonably assign to them given infiltration of surface water through the mechanism of fracture and matrix flow. The extent to which natural and waste package barriers can effectively assure a satisfactory performance of the disposal facility over the required isolation period has not been determined and may result in a determination of unsuitability separate and apart from the supergene/hypogene controversy. If the competing hypogene viewpoint were accepted, the prediction is that there is a high probability that water will be driven violently upward through available paths such as faults and fractures in association with the ascent and eruption of a gas-charged hydrothermal plume of water triggered by a tectonic event. Consequences of the upwelling would strongly depend on its timing. If hydrothermal fluids were to flood the proposed repository during a time when the facility is "hot" (i.e., during the initial several thousand years, when the temperature of the canister surfaces will exceed the boiling point of water), steam explosions undoubtedly would result and the canisters would be breached. A complete and rapid breakdown of the natural barriers as well as deterioration of all the engineered barriers would be expected. As the fissile material in the canisters becomes rearranged tremendous quantities of radioactivity would be released through a variety of pathways to the biosphere, not the least of which would be those created by predictable low yield nuclear explosions caused by uncontrollable *in situ* nuclear criticality processes. The releases of radionuclides directly into the atmosphere would be expected to yield widespread catastrophic (life-threatening) doses of nuclear radiation. If the inundation were to occur at later stages, within the regulatory time frame, the consequence would be a somewhat slower breakdown of natural and engineering barriers. Although in this case the consequences would not be catastrophic, the expected releases would be significant enough so that it would be very unlikely that the compliance of the proposed repository with any reasonable safety standards could be demonstrated.

As a predictive, decision aiding, tool the supergene-hypogene controversy should have been resolved on the basis of sound science before the Secretary of Energy recommended the site for development. At a minimum, the Congress and the President should have been completely informed of the existence of the issue before their decisions regarding the disposal and storage of radioactive waste and spent nuclear fuel at Yucca Mountain were addressed in 2001. The promise that "sound science" will prevail became a lie when President Bush on February 15, 2001 recommended approval of the Yucca Mountain site for the development as a repository to the Congress. The Congress passed the joint resolution approving Yucca Mountain and the President signed it into law on July 24, 2001.

The supergene-hypogene controversy remains unresolved. At this late date it is unlikely that any governmental entity, either State or Federal is willing, *sua sponte*, to invest suitable resources to seek an adequate resolution of the issue in advance of the DOE's filing of a license application with the Nuclear Regulatory Commission. It also appears that the State of Nevada has abandoned its role with

respect to this issue. It is now necessary, in the vacuum created by governmental neglect, for the concerned scientists to sound an alarm with the hope that it is not too late to effect remediation of the ill informed decision to approve Yucca Mountain as a repository. At this late date few people in positions of authority have an institutional memory of the history of the upwelling of water issue. The purpose of this document is to refresh that memory and, more importantly, to encourage any governmental or nongovernmental entity to address the seriousness of this issue and be prompted to do something about it.

History of the Issue

- 1954 Congress encouraged the private sector to become involved in the development of atomic energy for peaceful purposes under a program of federal regulation and licensing. The utilities that ventured into the nuclear power generating business were led to believe that nuclear fuel would be reprocessed and recycled and that repositories would be built when they were needed.
- 1976 As early as 1976 the Department of Energy suggested that Nevada sites as well as a number of other sites in other states were under consideration for disposal of high level radioactive waste.
- 10/18/77 The Department of Energy announced that it would take title to spent fuel which would be discharged from commercial nuclear reactors, and it would be responsible for both the storage and the ultimate disposal of that fuel. The Department was unable to provide a binding political commitment on behalf of the United States, however.
- 12/82 Congress enacted the Nuclear Waste Policy Act of 1982 (NWPA) which established a federal program for the siting and operation of geologic repositories for the disposal of high-level radioactive waste and spent nuclear fuel. The NWPA provided that the generators and owners of high-level radioactive waste and spent nuclear fuel had the primary responsibility to provide for, and pay the costs of, the interim storage of such waste and spent fuel until such waste and spent fuel was accepted by the Department of Energy. The NWPA established the Nuclear Waste Fund, composed of payments made by the generators and owners of high-level radioactive waste and spent fuel, to ensure that the costs of carrying out activities relating to the disposal of the waste and spent fuel would be borne by the generators. The nuclear utilities were to be charged a fee in an amount equivalent to 1.0 mil per kilowatt-hour for electricity generated by nuclear fuel and the fee is deposited in the Nuclear Waste Fund. The Secretary of Energy entered into contracts with generators of nuclear waste and spent fuel which provided that in return for the payment of fees the Secretary would dispose of the high-level radioactive waste or spent nuclear fuel no later than January 31, 1998. States that had candidate sites that were to be studied as potential repositories were to receive oversight funds from the Nuclear Waste Fund through grants administered by the Secretary of Energy. *See e.g., State of Nevada ex. rel. Loux v. Herrington*, 777 F.2d 529 (9th Cir. 1985). Regional equity was contemplated by locating repositories in the West and the East.
- 5/26/86 The Secretary of Energy identified sites in Nevada (Yucca Mountain), Texas (Deaf Smith County) and Washington (Hanford Reservation) for site characterization as candidates for a first repository and administratively dropped the search for a second

repository. The Yucca Mountain repository site is located in a layered formation of tuff in the "vadose" or "unsaturated zone", above the "saturated zone" or "water table." Tuff is a type of rock that results from hardening in various degrees of volcanic ash flow deposits.

11/1987

In November, 1987 Jerry S. Szymanski, a geologist working for the Department of Energy at DOE's Nevada Operations Office, Waste Management Project Office issued a report entitled "Conceptual Considerations of the Death Valley Groundwater System with Special Emphasis on the Adequacy of This System to Accommodate a High-Level Nuclear Waste Repository." It was transmitted to Carl P. Gertz, the Yucca Mountain Project Manager, on December 22, 1987. Szymanski developed a model which predicted episodic upwelling of ground water at Yucca Mountain in response to major tectonic events, which include moderate to large earthquakes and/or volcanic activity. His work was prompted by a concern which arose in 1984 when he conducted a tour for project scientists of Trench 14, which had been excavated across the Bow Ridge Fault on the northwestern slope of Yucca Mountain. He was justifiably concerned about the origin of the spectacular deposits of calcium carbonate which were exposed in the sides of the trench. He hypothesized that the deposits at Trench 14, like similar deposits in drill cores from boreholes, were caused by precipitated minerals from waters driven from great depths.

Szymanski's episodic upwelling of water model incorporated seismic pumping and gas-assisted, fracture controlled, thermal convection. It predicted the likelihood of the upwelling of large volumes of water which would flood the repository within the first few thousand years after emplacement of the waste. If such predictions materialized, the engineered containment of the waste could be expected to quickly fail as the result of the corrosive effects of heated water contacting and violently washing the high temperature surfaces of the canisters containing the spent fuel rods. If this happened, the engineered nuclear waste packages would be breached. Following canister failure the water would carry radioactive isotopes and hazardous chemicals into the biosphere with disastrous consequences.

If Szymanski's model were proved to be correct, Yucca Mountain would have to be disqualified as a repository site under NRC licensing regulations. Szymanski claimed that there was evidence that flooding at the repository horizon has repeatedly occurred in the past and could be expected to happen again. Szymanski recommended that "*serious consideration should be given to abandoning the Yucca Mountain site and declaring it as unsuitable for the purposes of permanent disposal of the high-level nuclear wastes.*" Szymanski's superiors at the Yucca Mountain Project Office in Las Vegas did not accept Szymanski's theories and continued to advise the Congress to the time of approval in 2001 that there was no scientific or technical reason why Yucca Mountain could not be developed as a repository. Such representations supported the decision by Congress to study Yucca Mountain as the sole site for development as the nation's first and only high-level radioactive waste and spent reactor fuel repository and its eventual approval for consideration by the NRC for licensing. DOE's official position developed from the hypothesis that the only water which will ever be available to corrode nuclear waste packages or carry radionuclides into the environment will precipitate from the atmosphere and percolate slowly downward through the earth to the saturated zone. This contention is only valid if the calcite-silica deposits in Trench 14 and similar deposits present at the repository horizon were deposited from above by meteoric water. No solid proof of that fact has ever been offered.

12/22/87

The Congress enacted the Nuclear Waste Policy Amendments Act of 1987 (NWPAA) on December 22, 1987. On December 15, 1987, conferees from the House of

Representatives and the Senate met and agreed to substantially redirect the nuclear waste disposal program by selecting Yucca Mountain, Nevada as the sole site to be characterized, thereby abandoning the site selection methodology set forth in the NWPA. In the 1987 Amendments Act, Congress also repealed the search for a second repository. The selection of Yucca Mountain was based primarily upon the relative lack of political power which the sparsely populated State of Nevada could muster to create an effective resistance.

7/26/1989 Jerry Szymanski transmitted a revision of his 1987 report to Carl Gertz, the Project Manager of the Yucca Mountain Project Office. The revised report responded to a large number of Yucca Mountain project scientists' comments on his previous report. Nevada Governor Richard H. Bryan had released a copy of the report to the public so Szymanski had also received many unsolicited comments that ran the gamut from encouraging and supportive to hostile and nasty. In the report he suggested a number of field investigations that could resolve the merits of his conceptual contentions.

11/19/90 William J. Broad published a lengthy article entitled "A Mountain of Trouble" in the New York Times Magazine describing Szymanski's theories. Broad put a face on the issue by his description of Szymanski's forced emigration from Poland, his successful employment with Dames & Moore and eventual employment with the DOE as the official in charge of packaging the data on Yucca Mountain for an eventual licensing proceeding. The article generated public interest and controversy.

1991 In the transmittal letter of his 1989 revised report, Jerry Szymanski requested an "external and independent peer review" of his report pursuant to an agreement a year earlier with Carl Gertz, the Project Manager. According to the agreement Jerry picked Professor Neville J. Price of the University College in London, England and Dr. Charles B. Archambeau of the University of Colorado in Boulder, Colorado. Professor Price was an internationally recognized authority in the area of structural geology, impact tectonics, rock mechanics and movement of fluids in the Earth's crust. Dr. Archambeau was a recognized expert in many aspects of geophysics and was familiar with the results of various geophysical investigations at the Nevada Test Site conducted the preceding 20 years. The DOE picked Dennis W. Powers, John W. Rudnicki and Leslie Smith. These were scientists that were connected with the Yucca Mountain Project in various capacities. The panel met in February 1991 and thereafter on five other occasions to hear presentations and examine the merits of Szymanski's contentions.

The protocol for the review called for a single report, but because of the division of opinion of the reviewers, a majority report and a minority report were prepared. The minority report, issued by Dr. Charles B. Archambeau and Professor Neville Price in 1991, strongly supported Mr. Szymanski's hypotheses while the majority report, also issued in 1991 by Dr.'s Dennis Powers, John Rudnicki and Leslie Smith, was critical in many respects. The three-to-two split did not resolve the issue with the degree of certainty required for an issue with such far reaching safety implications.

The DOE requested the National Academy of Sciences' National Research Council (NAS/NRC) to evaluate the Szymanski hypotheses. The DOE posed and the NAS/NRC addressed the wrong question, however. The NAS/NRC was asked "to assess the likelihood that the process described by the DOE scientist [Szymanski] could result in raising the water table to the level selected for the MGDS [mined geologic disposal system]." Szymanski never contended that the general water level would rise, rather that plumes of hydrothermal water would be forced upward through faults, fractures or any other available pathway in response to earthquake and tectonic driving processes. The NAS/NRC established the Panel on Coupled

Hydrologic/Tectonic/Hydrothermal Systems at Yucca Mountain, Nevada under the auspices of the Board on Radioactive Waste Management, to evaluate 1) if the water table had been raised in the geologically recent past to the level of the proposed mined geologic disposal system (MGDS) and 2) if it is likely that it will happen in the manner described by Mr. Szymanski within the 10,000-year period covered by the applicable federal regulations. The individuals appointed to the Panel on Coupled Systems claimed to have read Mr. Szymanski's report and other pertinent literature, and interviewed or consulted with scientists involved in field and laboratory investigations of Yucca Mountain and the surrounding region for the DOE, the State of Nevada, independent scientists, and the five members of the External Review Panel.

- 11/1991 Technology and Resource Assessment Corporation (TRAC) was formed in November 1991 and subsequently obtained a contract from the Nevada Nuclear Waste Projects Office to conduct research on the suitability of the proposed Yucca Mountain repository.
- 4/17/1992 On April 17, 1992 the DOE received the NAS/NRC Panel on Coupled Systems final report entitled "Ground Water at Yucca Mountain, How High Can It Rise." The Panel's overall conclusion in the report "... *was that none of the evidence cited as proof of ground-water upwelling in and around Yucca Mountain could be reasonably attributed to that process.*" The NAS/NRC Panel report spawned a number of critical reviews which strongly questioned the validity of the Panel's conclusions on scientific grounds. The ensuing debate over the accuracy and veracity of the NAS/NRC Panel report has never been resolved.
- 5/1992 Jerry Szymanski resigned his position with the DOE on May 1, 1992. At the time he quit he had been relegated to a small office with no windows and no duties. At least two other scientists left with him. One, Dr. Donald Livingston, went to work for Technology Resources Assessment Corporation (TRAC). He commented in an article published in the Las Vegas Sun, Nov. 12, 1992, at p. 6A that "*It's perfectly obvious to us that the report by the Academy (NRC) is a very, very bad report. They've ignored data and misrepresented things.*" Dr. Gerald A. Frazier left SAIC, a DOE contractor. Dr. Frazier wrote the preface to Szymanski's 1989 report. In it he remarked that since Szymanski's hypotheses are plausible, "*...the 'burden of proof' is ours, the scientists who are responsible for investigating the site.*"
- 9/17/93 On September 17, 1993, the DOE issued a report entitled "Report On The Origin Of Calcite-Silica Deposits At Trench 14 And Busted Butte And Methodologies Used To Determine Their Origin", YMP/93-11-R. With that report, DOE closed its investigation of the calcite-silica deposits and the possible groundwater origin issue as far as the surface deposits were concerned. This action presaged the DOE's eventual position on the overall upwelling of water issue. The DOE's report stated at Section 1.3 of the Introductory Chapter:

The current data and analyses, presented in Chapter 2, indicate that ground water did not rise to the surface during the Quaternary and produce the deposits found at Trench 14 and Busted Butte. Therefore, based on this analysis of the information gathered thus far, the DOE finds no basis to continue specific studies to determine the origin of these deposits. Those efforts are complete, but the DOE will continue related characterization activities designed to evaluate calcite-silica deposits from core retrieved in the drilling program for site characterization and from samples taken during underground excavations.

In effect, the DOE determined that the origin of the calcite-silica deposits in Trench 14 had been resolved. In the Executive Summary of the DOE report, the DOE determined that the calcite-silica deposits were the result of pedogenic processes:

Analysis of data obtained in geochemical, isotopic, mineralogic, geologic, paleontologic, field and morphological studies supports only the pedogenic model for the calcite-silica deposits. Data obtained from geochemical, mineralogic, geological and geochronological studies support a combination of ancient (more than 10 million years) pyroclastic-hydrothermal processes and modification by more recent surficial processes to account for older silica deposits and breccias. Therefore, based on the data and analyses, the DOE concludes that the calcite-silica deposits in Trench 14 and Busted Butte at the Yucca Mountain site are the result of processes consistent with a pedogenic origin.

1992

The State of Nevada's Nuclear Waste Project Office engaged the services of Technology and Resource Assessment Corporation-North America (TRAC-NA) for the purpose of critically evaluating the problems raised by Jerry Szymanski and the treatment given to them by the NAS/NRC Panel on Coupled Systems on DOE's behalf. On November 19, 1992, Dr. Charles B. Archambeau, of TRAC, wrote to Dr. Frank Press, President of the National Academy of Sciences as follows:

[W]e have reviewed the National Academy of Sciences' report generated by the Panel on Coupled Hydrologic/Tectonic/Hydrothermal Systems at Yucca Mountain, as previously noted . . . [W]e disagree with most of the conclusions and recommendations made in the report. Therefore, this is not what might be termed a "disagreement about scientific details" but a major criticism directed at the Panel for their disregard of critical data that was available and known to them, their misrepresentation of other data and results, and the use of equivocal and often contradictory field "observations" and data to draw very strong conclusions and recommendations.

The Nuclear Waste Project Office was represented at this time by Senior Deputy Attorney General (SDAG) Harry Swainston. He discussed at length the deficiencies of the NAS/NRC Panel on Coupled Systems report with Dr. Archambeau and Jerry Szymanski, who by this time had become an employee of TRAC. Swainston suggested that the Nevada Attorney General might be able to discover the basis for the report by deposing the scientists involved.

Swainston was convinced that it was a critical consideration with respect to the safety evaluation of the Yucca Mountain site to establish whether the deposits were precipitated from descending rainwater by evaporation at and near the topographic surface or by warm or hot solutions upwelling from the interior of Yucca Mountain. He realized that the issue would be of critical importance in the NRC licensing proceeding. Two cases were evident. If the deposits were supergene in origin, the associated geologic processes still pose a threat to the proposed facility, but one which is dependent upon the descending groundwater travel time, which was generally conceded to be controlled by fracture flow. But, if the deposits were precipitated from hypogene solutions, ascending along active faults and fracture zones at and near Yucca Mountain, then such solutions would likely breach the canisters in the proposed facility during the lifetime of the repository. Such an event could lead to environmental consequences that would reach well beyond the borders of Nevada and be catastrophic in scope. Unquestionably, in the latter case, uncertainties regarding the long-term performance of the proposed facility would be

sufficiently high to withhold licensing of Yucca Mountain site as a repository.

1993 The State of Nevada obtained, through a request from the Nuclear Waste Project Office (NWPO), the DOE data on the fluid inclusion homogenization temperatures for the unsaturated-zone calcites from two boreholes drilled at Yucca Mountain. The measurements were performed in 1992-1993 for the USGS by a former member of the NAS/NRC Panel on Coupled Processes at Yucca Mountain, a Harvard Professor, Edwin Roedder. The data set included several values of 70 to 102 °C – clearly hydrothermal temperatures. During the subsequent 10 years or so, these temperatures were not cited or mentioned in any of the USGS or DOE technical publications. The USGS researchers working for the DOE Yucca Mountain project adopted an interpretation whereby secondary calcite at Yucca Mountain was deposited from infiltrating cold rainwater. They have stuck tenaciously to this interpretation while disregarding (and withholding) their own data.

6/14/93 On June 14, 1993 SDAG Swainston, on behalf of the State of Nevada Attorney General, submitted a verified petition in the nature of a complaint, to the District Court of Nevada, pursuant to Federal Rule of Civil Procedure 27. It sought to perpetuate testimony related to the per descensum/per ascensum controversy for later use in licensing and judicial review proceedings in which Nevada would be entitled to be involved by virtue of its oversight role. The single most important administrative proceeding in which Nevada and the Department of Energy anticipated involvement would be the Nuclear Regulatory Commission's proceeding to license the construction of a repository. During this proceeding the Nuclear Regulatory Commission would be required to apply its Technical Requirements and Criteria, 42 U.S.C. §10134. The proceeding would be comprehensive in nature spanning an expected three year period.

The petition filed with the District Court proposed perpetuating the testimony, by deposition, of the scientists who reviewed various aspects of the hydrothermal water upwelling issue, particularly those scientists on the NAS/NRC Panel on Coupled Systems.

10/5/93 On October 5, 1993, without notice or hearing the District Court dismissed Nevada's petition. Nevada immediately moved the Court to reconsider and requested a hearing. On November 24, 1993, the District Court, again without notice or hearing, denied Nevada's motion to reconsider. The District Court's October 5 Order was based upon one essential finding of fact: that the testimony Nevada sought to perpetuate by deposition "is already available, in an appropriate form reviewable by the appellate court." October 5 Order at p. 7. The Court reaffirmed this finding in its November 24, Minutes of the Court Order:

... [T]here are numerous safeguards and record keeping procedures that assure that the relevant information will be available should Nevada feel compelled to bring suit in the future

12/22/93 Nevada filed its Notice of Appeal to the Ninth Circuit Court of Appeals on December 22, 1993. On appeal Nevada's lawyers argued that the NAS/NRC Panel report must stand on its own merits, whatever they may be and Nevada should be entitled in the future to put the report in the proper light by the testimony of its authors and critics. Nevada sought to perpetuate the testimony of individual scientists whether they agreed with the report or not. It was the testimony of the scientists which was at issue, not the report. Furthermore, they argued that there will not be "numerous safeguards and record-keeping procedures" to permit Nevada to establish a basis for the opinions of the individual researchers who reviewed Mr. Szymanski's hypotheses. As they

- pointed out in arguments before the District Court, it is likely that most of the scientists will be unavailable at the time when administrative proceedings, or the federal court actions reviewing them, are ripe. On August 25, 1995 a panel of the Ninth Circuit Court of Appeals denied the State's appeal on the basis that Rule 27 could not be used to do discovery. *See, State of Nevada v. O'Leary*, 63 F.3d 932 (1993)
- 3/31/94 On March 31, 1994 a companion case to the Rule 27 perpetuation of testimony case was commenced by SDAG Swainston in the Ninth Circuit Court of Appeals seeking an order requiring the then Secretary of Energy, Hazel O'Leary, to continue the study of the nature and origin of the calcite-silica deposits in Trench 14. The State of Nevada's Complaint was based upon "*the Secretary of Energy's failure to carry out ... appropriate site characterization activities*" required by 42 U.S.C. 10133(a) with respect to the study of Trench 14. On June 6, 1995 the Ninth Circuit Court of Appeals denied the State's petition in an unpublished memorandum opinion on the basis that the Secretary of Energy has broad discretion to determine to study or not to study.
- 1994-1996 The DOE excavated an exploratory tunnel (Exploratory Studies Facility, ESF) around a 5 mile loop within the repository footprint. More occurrences of secondary calcite, opal and other hydrogenic (i.e., deposited from waters that circulated through the rocks) minerals become accessible and available for detailed studies.
- 3/5/95 William J. Broad added another chapter to the "Mountain of Trouble." In an article entitled "*Scientists Fear Atomic Explosion Of Buried Waste*" published in the New York Times on March 3, 1995 at page 1, column 1, he reported that "*a debate had broken out among Federal scientists over the planned underground dump for the nation's high level atomic wastes in Nevada might erupt in a nuclear explosion, scattering radioactivity to the winds or into ground water or both.*" He wrote that the debate had been set off by two scientists from the Los Alamos National Laboratory, Dr. Charles D. Bowman and Dr. Fransesco Venneri. The two scientists, in a report issued by the LANL entitled "*Underground Supercriticality From Plutonium and Other Fissile Material,*" concluded that if the canisters of spent fuel are breached and the contents are rearranged by preferential leaching in proximity to the type of rock found in Yucca Mountain "*explosions of significant nuclear yield can occur.*" Their findings were confirmed by DOE researchers at Savannah River near Aiken, South Carolina although some of them, loyal to DOE's mission, denied that any water would be present at Yucca Mountain to facilitate the rearrangement of the fissile material.
- 1995 Dr. D. Norman from New Mexico Tech and LANL researchers, Drs. S. Levy and D. Vaniman, developed a method for discriminating between calcites of different origins. They studied the chemistry of gases trapped in inclusions. The method was developed specifically for eventual application at Yucca Mountain (the research was funded by DOE). They found that calcites formed in the saturated and unsaturated environment have distinct gas chemistries. Their method was described and the results were published in a peer-reviewed journal (*Chemical Geology*, Elsevier, 1995).
- In the same year, these researchers analyzed three samples from the exploratory tunnel excavated at Yucca Mountain (Exploratory Studies Facility, ESF) and Trench 14 by the methodology published in *Chemical Geology*. Their results showed that the Yucca Mountain calcite was formed in saturated conditions and in a reduced environment – in stark contrast with the pedogenic origin postulated for these deposits by the DOE researchers. The data are not included in subsequent DOE reports as they were "non QA" (QA stands for quality assurance) and because they

- were "... obtained outside the Site Characterization Plan." This line of research was abandoned; no single new measurement was made between 1995 and 2005.
- 5/1996 TRAC-NA submitted its Final Report to the Nevada Nuclear Waste Project Office in May 1996. The report included the first complete reports by Dr. Dublyansky and V. Reutski documenting the elevated-temperature fluid inclusions in calcites within the ESF. The report contained other lines of evidence suggesting the validity of Jerry Szymanski's hypothesis that the calcite-silica deposits in the veins and fractures were caused by depositions from water upwelling from great depths beneath Yucca Mountain. Attachment A to the report was concerned with the origin of particular geologic deposits at Yucca Mountain, which were critically important to an understanding of the recent geologic history of the site. Specifically, the controversial deposits were: 1) crystalline quartz and calcite from the vadose zone, 2) so-called AMC breccias from the topographic surface and 3) calcite-silica veins and slope calcretes from the topographic surface. The origin of these deposits as well as the character of geologic processes that were responsible for them remains in dispute.
- 1/97 In January 1997, Jerry Szymanski petitioned the Nuclear Waste Technical Review Board to consider evidence of his upwelling hypothesis which had accumulated since the NAS/NRC review in 1992.
- 3/25/97 A letter sent to Dr. Jared Cohen, Chairman of the Nuclear Waste Technical Review Board, (NWTRB) on March 25, 1997, authored by SDAG Swainston and signed by Nevada Attorney General Frankie Sue Del Papa, supported Szymanski's petition to the NWTRB to reopen the issue citing an interest of her office which stemmed from the two court cases discussed above dealing with the upwelling issue. She requested that the Board investigate the potential for flooding of a proposed repository at Yucca Mountain. "*It is clear that the Board has the jurisdiction and duty to inquire into this very serious charge against the suitability of the site and to resolve it to the Board's satisfaction,*" Del Papa's letter stated. Pledging the support and assistance from her office, she asked to be kept "*informed as to how the Board intends to address this important issue.*" She cited reports and provided others which had been compiled by a team of international scientists that contain the physical evidence for hydrothermal water being driven from under Yucca Mountain into the repository horizon in the recent geologic past. "*If the Board will give this evidence a fair review,*" she said, "*it will be forced to a conclusion that Yucca Mountain is not suitable for a repository.*"
- 11/12/97 On November 12, 1997, the NWTRB agreed to evaluate the quality and significance of new information pertaining to the upwelling hypothesis. Three scientists were put under contract to assist in the evaluation. These were Dr. Robert J. Bodnar, a professor of geologic sciences from Virginia Polytechnic & State University; Dr. Patrick R.L. Browne, a professor and director of the Geothermal Institute of the University of Auckland in New Zealand; and Dr. John W. Valley professor and chairman of the Department of Geology and Geophysics at the University of Wisconsin.
- 1/21/1998 A contract was approved by the Nevada Board of Examiners between the Nevada Attorney General and Jerry Szymanski for services as a consultant. The contract retained Szymanski to serve as a scientific adviser with the expectation that he would provide expert testimony before the NRC licensing board and the courts when the need arose. Szymanski's contract was discontinued in January 2003 after Attorney General Del Papa left office.
- 3/98 In March 1998, Dr. Bodnar indicated a desire which was transmitted to SDAG Swainston through the staff at the NWTRB to confer with Dr. Yuri Dublyansky, a

Russian scientist with international expertise in fluid inclusions, and a former consultant to TRAC-NA, who lead the research on the fluid inclusions in calcite from the ESF. SDAG Swainston, advised an employee of the NWTRB, Dr. Leon Reiter, of the Attorney General's interest in facilitating a meeting with Dr. Bodnar and Dr. Dublyansky. Dr. Reiter mentioned that a fluid inclusion conference was to be held in Las Vegas in June 1998, at which time Dr. Edwin Roedder would present a paper describing fluid inclusion studies that would refute the upwelling hypothesis. Dr. Bodnar would be in attendance. The Deputy AG contacted the conference organizer, Dr. Jean Cline at UNLV, and told her that the State would have presented a rebuttal paper if the State had had notice of the Conference. She said it was not too late. Dr. Dublyansky was contacted and a contract was approved for him to appear and present a paper on behalf of the State at the Conference.

3/27/98

Science magazine reported on March 27, 1998 that a study commissioned by the Nuclear Regulatory Commission and conducted by a team of scientists from the California Institute of Technology led by Dr. Brian Wernicke suggested that Yucca Mountain was undergoing greater extensional strain rates than previously reported by the DOE. The article, authored by Professor Wernicke and eight of his colleagues, suggested that earth strain rates observed in the vicinity of Yucca Mountain were a factor of ten greater than the DOE had previously reported. Wernicke and his colleagues suggested that one reason for the expansion is hot mantle beneath the crust at Yucca Mountain. The increased expansion amplified the potential for volcanism, and seismicity in the Yucca Mountain area.

4/16/98

In a letter dated April 16, 1998, the Attorney General petitioned Lake Barrett, Acting Director of the Office of Civilian Radioactive Waste Management, to recognize the commitment made in the Ninth Circuit Court of Appeals case, *Nevada v. O'Leary*, Case No. 94-70148, to continue the study of the nature and origin of the calcite-silica deposits in the Exploratory Study Facility in connection with the upwelling debate. A thorough review of the opposing views and supporting evidence was provided. The Attorney General requested that the Secretary of Energy provide funds to Nevada's Nuclear Waste Projects Office to allow Nevada's scientists to further validate the upwelling hypothesis. No response was received to the letter.

5/18/98

On May 8, 1998, the Nevada Attorney General again wrote to Lake Barrett advising him of the results of studies done by Professor B. Wernicke and his colleagues. Their investigations were based upon a state-of-the-art technique whereby Global Positioning System data taken from stable geodetic monuments was subjected to differential analysis. The strain rates were determined to be at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. Such high rates of strain, if confirmed, would seriously implicate the geologic instability of the Yucca Mountain area. Such geologic instability would have a direct bearing upon the supergene-hypogene controversy in addition to other disqualifying conditions associated with the recurrence of large earthquakes. The Attorney General stated that the State of Nevada had been presented a proposal from TRAC-NA to study the implications of the enlarged strain rates in connection with the suitability of Yucca Mountain and requested DOE funding for these critical investigations. No response was received from Barrett to the letter.

The two proposals submitted by TRAC-NA to the Attorney General identified a premise that the most serious future threat to nuclear waste containment at Yucca Mountain is earthquake or volcanically driven ground water intrusion into the proposed underground storage area which would result in the relatively rapid breakdown of the hot metal canisters encasing the waste by water and steam activated corrosive processes. The purpose of the first proposal for absolute age dating and gas-

fluid inclusion studies was to establish the recurrence period for the tectonically induced episodic hydrothermal eruptions and the distribution of such periods over the past 8 million years. It would have cost \$162,347.50. The purpose of the second proposal was to determine the current and future likelihood of earthquake and volcanic activity at Yucca Mountain as direct evidence of a volcanic state which may lead to ground water intrusions and how often such intrusions could take place in the next several thousand years. The proposal would have required the installation of several seismic micro-arrays at and near Yucca Mountain to determine the presence and orientation of local active faults, determine the presence or absence of zones of dilatancy and determine the presence or absence of bodies of magma. Such studies would have provided the data base from which to infer the local recurrence times for large earthquakes, the faults along which these earthquakes would most likely occur and the magnitude of potential earthquakes which may trigger upwelling episodes during the lifetime of a proposed repository. It would have required considerable data transmission and analysis over a period of approximately two years. Its cost would have been \$467,994. The proposals became tied to SB 206 in the 1999 Legislature since the DOE ignored the request for funding. SB 206 did not pass because the committee of jurisdiction failed to bring the measure to a vote.

- 6/2/98 On June 2, 1998, USGS researchers Prof. E. Roedder and Dr. J. Whelan gave a talk at the International Fluid Inclusion Meeting in Las Vegas (PACROFI-VI) stating that calcite from the ESF does not contain two-phase fluid inclusions and, therefore, was formed at ambient temperature from infiltrating rainwater. Dr. Dublyansky appeared at the PACROFI-VI conference on behalf of the Nevada Attorney General and rebutted Dr. Edwin Roedder's descending rainwater hypothesis based upon his fluid inclusion studies. His presentation was reported in the press and his views were subsequently raised to national importance.
- 6/8/98 On June 8-9, 1998, Dr. Dublyansky collected additional samples from the Yucca Mountain tunnel for fluid inclusion analysis in anticipation of a possible presentation at the Geological Society of America Conference in Toronto, Canada at the end of October 1998.
- 10/98 After Dr. Dublyansky completed his contract with the Attorney General office he went to Washington D.C. and began a consulting arrangement with a public interest organization, the Institute for Energy and Environmental Research (IEER), which was interested in suitability issues relative to Yucca Mountain and had an associated interest in canister corrosion. During his stay in Washington he went to the laboratory of Dr. Robert Bodnar at Blacksburg, Virginia, and collaborated with Dr. Bodnar in the analysis of some of the samples which were the subject of Dr. Dublyansky's Las Vegas presentation. The purpose of this work was to examine the hypothesis, proposed by Bodnar, that the high temperatures reported earlier by Dublyansky may have been the result of improper sample preparation and/or data collection techniques. The results were replicated to Dr. Bodnar's satisfaction. In the follow-up letter sent to NWTRB on July 08, 1998, Dr. Bodnar stated:

The most important result of the work conducted in the Fluids Research Laboratory during the week of June 15-19, 1998, is that the high temperatures reported earlier by Dublyansky were confirmed to be real and not an artifact of sample preparation or data collection. There is little doubt that the calcite in sample SS#85-86 was either formed at or later exposed to aqueous fluids with temperatures of at least 72°C.

Crushing tests on 4 all-gas inclusions indicated that all 4 inclusions had internal pressures less than one atmosphere, suggesting that the

inclusions do not contain air that was trapped at one-atmosphere in the unsaturated zone. This indicates that the inclusions could not have been trapped at one atmosphere in the vadose zone.

7/24/98 On July 24, 1998, the NWTRB prematurely issued its review of the upwelling hypothesis rejecting the suggestion that the new material which had been presented to the Board made a credible case for the assertion that there has been ongoing, intermittent hydrothermal activity at Yucca Mountain or that large earthquake-induced changes in the water table are likely at Yucca Mountain. The NWTRB stated in its report that:

...fluid inclusions found in mineral deposits at Yucca Mountain do provide direct evidence of the past presence of fluids at elevated temperature (at least 72°C) in the vicinity of the proposed repository. This could be an indicator of some degree of past hydrothermal activity.... The Board believes that the ages of fluid inclusions should be determined. A joint program between federal and State of Nevada scientists for collecting, dating, and analyzing fluid inclusions would be one way to help eliminate some of the past disagreements associated with sample collection and handling.

For some reason, the Board considered "*... additional research on these issues as generally having a lower priority than more important issues in the evaluation of repository performance.*"

While the NWTRB's July 24, 1998 report stated that the new "*data and interpretations do not significantly affect the conclusions of the 1992 NAS report,*" the report was equivocal in important respects and left the door open for confirmation of the hypogene theory. Dr. Dublyansky's review of the NWTRB report and technical reports of the Board's scientific consultants suggested that they were not in disagreement with the hypogene theory, but rather they believed that it could be confirmed or disproved by appropriate investigations. Their views were consistent with the Board's recommendation of a joint program to eliminate past disagreements.

8/31/98 SDAG Swainston retired from the Attorney Generals Office at the end of May 1998 and began a two year consulting contract with the Office on August 31, 1998. Swainston agreed to provide professional services in connection with the preparation of evidence and the identification of expert witnesses for a possible licensing proceeding before the licensing board of the Nuclear Regulatory Commission.

9/98 A contract to be administered by TRAC-NA was approved by the Board of Examiners in September 1998 to permit Dr. Dublyansky and Dr. Alexander V. Chepizhko of the Odessa State University, Ukraine to present papers at the Annual Meeting of the Geological Society of America in Toronto concerning evidence of the upwelling process.

9/3/98 On September 3, 1998, J. Russell Dyer, Project Manager for the DOE's Yucca Mountain Project, in a letter to Bob Loux, Executive Director of the Nevada Nuclear Waste Projects Office, proposed a joint scientific inquiry between the State and the DOE that might resolve the upwelling of water controversy.

10/26/98 On October 26, 1998, Dr. Yuri Dublyansky and Dr. Alexander Chepizhko presented their papers in Toronto. A flurry of press in the Las Vegas papers described the doubts raised by the papers as to the suitability of Yucca Mountain. At one of the appearances of Secretary of Energy Bill Richardson on October 27 in Las Vegas, a

copy of Dr. Dublyansky's paper was given to him. The following morning at a press conference he was asked about Dr. Dublyansky's studies and responded that he intended to review the new evidence about thermal water having risen within the mountain, adding, "*science will dictate the answer.*"

- 11/6/98 On November 6, 1998, Dr. Dublyansky and Dr. Chepizhko presented their findings to a small group at the Attorney General's Office. Senator Mark Amodei attended. At the Senator's suggestion a Bill Draft Request was prepared which would state the policy of the 1999 legislature to file a notice of disapproval and direct the Nevada's Nuclear Waste Project Office to commence the preparation of a statement of reasons to accompany such a notice. The bill surfaced as SB 206 in the 1999 legislative session. The Nevada Attorney General's office lobbied for its enactment. It was approved in the Senate Environment Committee, one of the committees with jurisdiction and was referred to the Senate Finance Committee because there was a fiscal note. Of particular importance to the Attorney General was the fiscal appropriation of \$1 million dollars to accomplish the purposes of the bill. The funds, had they been appropriated, would have funded the proposals submitted to the Attorney General by Dr. Archambeau of TRAC-NA. The bill failed because the Chairman of the Senate Finance Committee refused to bring the bill to a vote in his Committee. SDAG Swainston was so incensed he resigned his contract with the Attorney General and wrote a scathing letter to the editors of a number of Nevada newspapers condemning the treatment given to SB 206. He later agreed to rescind the resignation, but the Senate Finance Chairman refused to fund his contract a year later in retaliation, effectively terminating Swainston's contract. He would continue his association with the concerned scientists to the present on a *pro bono* basis.
- 9-10/1998 In September-October 1998 Dr. Dublyansky performed detailed fluid inclusion studies on several calcite samples from the ESF at Dr. Bodnar's laboratory at Virginia Tech. These studies were sponsored by IEER. Dr. Dublyansky concluded with respect to these studies that it was indisputable that the formation of a substantial part (if not all) of the calcite taken from the ESF was from fluids with elevated temperatures.
- 11/4/98 On November 4, 1998, Dr. Dublyansky received an invitation to participate in a special session on nuclear waste and Yucca Mountain at the American Geophysical Union meeting at Harvard University in Boston in June, 1999. It was anticipated that the Harvard conference would fuel the debate on the suitability of Yucca Mountain. All of the major players were invited to participate. Dr. Charles Archambeau, President of TRAC-NA, Jerry Szymanski, as well as Dr. Dublyansky, were scheduled to present papers at the conference.
- 11/98 On November 16, 1998, Dr. Dublyansky returned to Washington D.C. for the purpose of working with the Institute for Energy and Environmental Research in the preparation of a report of the results of his investigations on the Yucca Mountain fluid inclusions samples. The report was peer reviewed favorably by fluid inclusion experts from England (Prof. Bruce Yardley), Austria (Prof. Larryn Diamond), and France (Prof. Jean Dubesy). A review from the United States (Dr. Jean Cline of UNLV) was neutral; and a very negative review was submitted by a group of the USGS scientists working in the Yucca Mountain project. Dublyansky responded to his critics in the final version of the report.

The data presented in the reports along with some additional data collected in 1999 were published as a peer-reviewed paper in a professional journal (Chemical Geology, Elsevier) in 2001.

- 12/1/98 On December 1, 1998, a press conference was held in Washington D.C. at which time Dr. Dublyansky presented his findings in connection with IEER's effort to challenge the signing by the Secretary of Energy of the Viability Assessment. IEER supported over 200 environmental organizations which called upon the Secretary of Energy to disqualify the Yucca Mountain site and to delay the issuance of the Viability Assessment. These petitions were unsuccessful, however. The Viability Assessment was released in December 1998.
- 12/3/98 On December 3, 1998 Dr. Dublyansky returned to Las Vegas after the December 1 press conference in Washington D.C. to take additional samples in the ESF (primarily from sites at which the USGS researchers had obtained their data). He then returned to Russia to prepare the samples for subsequent analysis to be conducted at Dr. Bodnar's laboratory in Blacksburg, Virginia during the spring of 1999 in preparation for the Boston conference.
- 12/98 The DOE redirected the Yucca Mountain program into a phase which it called a "viability assessment." This is a term which was not defined or mentioned in the NWPA. The Viability Assessment Report, released to the public in December 1998, was a five volume synthesis of the DOE's 15 years of studies of Yucca Mountain as a potential repository.

Evidence of hydrothermal activity within the unsaturated zone at Yucca Mountain was available before the issuance by the DOE of both the Viability Assessment and the Draft Environmental Impact Statement (July 1999). Inexplicably, the possibility of hydrothermal flooding of the proposed repository was ruled out. The following statement in the DEIS (p. 3-49) is consistent with what would become DOE's official position with regard to this issue:

DOE given the opportunity to review a preliminary version of the report [Dublyansky, Fluid Inclusion Studies of Samples from the Exploratory Studies Facility, Yucca Mountain, Nevada, 1998], arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert (Dr. Jean Cline of UNLV). This group did not concur with the conclusion in the report by Dublyansky (1998).

The account quoted above is clearly biased, in that the positive reviews of the report by as many as three recognized European experts on fluid inclusions are not mentioned, and one neutral noncommittal review (by Dr. Cline) is "counted" as negative.

The DOE suggested in its Viability Assessment that it had not uncovered any surprises which it regarded as adversely affecting the determination of suitability, and it continued to disregard developments in connection with the investigation of upwelling of water within the repository in the recent geologic past.

- 1/99 In January, 1999, a proposal from Jean Cline, the manager of the proposed joint DOE/State project (the UNLV Yucca Mountain Thermochronology Project) was submitted to the DOE describing the participation of the DOE and the State of Nevada in the proposed joint study. When the proposal from Jean Cline was received, it was apparent that the State was to have little involvement in the actual laboratory work. Dr. Yuri Dublyansky was to participate as the State's representative in periodic review sessions but the proposal, as formulated, did not promise to resolve the disagreement which prompted it.

The Nevada Attorney General's concept of a joint study would have included the following essentials: 1) a joint review of the contentious issues; 2) the development of a common issue resolution approach; 3) a collection of a common set of samples of the controversial deposits; 4) an application of the same methodologies in analyzing the samples; 5) an exchange and discussion of the results; and finally 6) the development of a consensus report.

4/1999

Dr. Bodnar, one of the NWTRB consultants during the 1998 review of the upwelling issue, and independent expert for the UNLV Thermochemistry Project in 1999-2001, stated in an article published in *Supplement to EOS* on April 27, 1999:

Those scientists who have examined the recent data are in general agreement that waters of unknown but, presumably, deep origin have entered the repository horizon at some time during the geologic past. ... The problem as it relates to the suitability of Yucca Mountain as a nuclear waste repository concerns the timing of fluid infiltration.

4/28/1999

On April 28, 1999, the USGS issued Circular 1184 entitled "*Yucca Mountain as a Radioactive-Waste Repository.*" In Circular 1184 DOE's strategy with regard to postclosure repository performance was described as being founded on four key attributes: (1) limited water contacting the waste packages, (2) long waste-package lifetime, (3) low rate of release of radionuclides from breached waste packages, and (4) radionuclide-concentration reduction during transport from the waste packages. Associated with the four key attributes were 19 principal factors governing the postclosure performance of the proposed repository. The 19 principal factors outline a sequence of processes, conditions, and events that collectively define the expected behavior of the repository system. "Unexpected behavior" referred to the effects on system performance caused by infrequent, unlikely events. As to the attribute having to do with limited water contacting the waste packages, 6 principal factors were identified: (1) precipitation and infiltration into the mountain, (2) percolation to depth, (3-) seepage into drifts, (4) effects of heat and excavation on flow, (5) dripping onto the waste package, and (6) humidity and temperature of the waste package. The potential for the upwelling of large quantities of water from beneath Yucca Mountain was not considered as a factor. Consideration of the broad category of "seepage into drifts" was limited to seepage controlled primarily by percolation in the unsaturated zone at the repository level.

In an appendix to the circular entitled "Paleohydrologic Significance Of Secondary Minerals In The Exploratory Studies Facility," the USGS authors stated that "*Inspection of hundreds of open fractures, faults and other void spaces (lithophysae) along the 8 km of underground drifts at the Exploratory Studies Facility by Zell Peterman and other U. S. Geological Survey scientists have shown the near-absence of secondary minerals (chiefly calcite and opal) commonly precipitated by ground water moving through rhyolitic volcanic rocks.*" The scientists observed with regard to the calcite and opal deposits that the "*secondary-mineral coatings indicate an extremely slow, relatively constant rate of deposition for millions of years*" and "*the presence of these deposits only on fissure footwalls and in the lower half of lithophysal cavities provides unequivocal evidence that they are of vadose origin.*"

6/1/1999

On June 1, 1999 the DOE and USGS issued a joint press release which boldly proclaimed that "Yucca Mountain is high and dry." The press release was issued in conjunction with a news conference held in Boston, Mass., during the American Geophysical Union Spring meeting. According to the release:

There is no evidence at Yucca Mountain, based on the distribution of calcite and opal, that water has ever flooded the potential nuclear waste repository area," said James Paces, a USGS scientist from Denver, Colo. Paces described cavities in the volcanic mountain's interior as being relatively free of deposits of calcite and opal, and where they are found these deposits are restricted mostly to the lower surfaces. "If water had filled the cavities, minerals would have been deposited on the walls and ceilings as well," Paces said. "Instead, our data indicate that the minerals formed from thin films of water flowing downward into open spaces."

While Yucca Mountain may appear high and dry, it has not had a history of highness and dryness. The USGS made the same mistake that the National Academy of Science's Panel on Coupled Systems did in its final report entitled "Ground Water at Yucca Mountain, How High Can It Rise." The error involves the assumption that the water table rose to a level that exceeded the proposed repository horizon. This was not and has never been the position of Jerry Szymanski or the concerned scientists. The flows of warm or hot water described by them were necessarily episodic. They would have to be short lived and erratic in time and space, and confined primarily to the spatially separated fracture zones and faults. How far each plume would disperse in a lateral direction is not easily determined. The description, however, is of plumes of upward driven water rather than a general rise in the water table. The water in such plumes would naturally disperse laterally at any elevation possible. Such lateral penetration would be more restricted in the subsurface that was already saturated with water. But in the unsaturated zone and at the surface lateral movement was not only possible but to be expected. In the unsaturated zone there was also water infiltrating from the surface. As the hydrothermally driven water mixed with cooler water infiltrating from the surface, the mixing would cause the physical and chemical constituents in the mixed water to represent to a lesser or greater degree the chemical signatures of the end member parental waters depending on the distance from the fault or fracture zone that transported the upwelling water and other factors such as permeability and conductivity. As a consequence it would be expected that water may not actually fill all the cavities, but certainly most of the crystals that were fully developed, were totally immersed in the depositing fluids. The USGS scientists have attempted to explain the fully formed development of the crystals as being caused by capillary action rather than submersion.

- 6/2/1999 Dr. Yuri Dublyansky presented a talk at the American Geophysical Union meeting in Boston. Dr. Dublyansky reported on his fluid inclusion studies, which indicated a hydrothermal origin of calcite at Yucca Mountain and thereby cast serious doubt on the DOE/USGS "high and dry" thesis. Most of the major players that were interested on both sides of the hydrothermal upwelling of water controversy as well as people who might contribute to the future resolution of the controversy were present. The debate was reported in Volume 155 of *Science News* at pp. 374-375 on June 12, 1999.
- 11/1999 At a meeting of the UNLV project participants held in November 1999 the USGS researchers presented a new hypothesis to explain the elevated temperatures of the fluids forming the secondary deposits in the ESF. They hypothesized that percolating rainwater could have been heated by residual heat of the tuffs or by conductive heat emanating from a magma body underneath the Timber Mountain caldera. Dr. Dublyansky was dubious, because for the USGS hypothesis to be correct rocks in the Yucca Mountain unsaturated zone must have maintained elevated temperatures (up to 75 °C) for up to 6-8 million years.
- Dr. Dublyansky, at a meeting of the participants of the UNLV Thermochronology project in 2000, requested USGS researcher Dr. J. Whelan to carry out a formal

evaluation of the USGS thermal model. He agreed but never provided Dr. Dublyansky with technical data in support of the model.

In 2001, USGS researchers, Drs. Marshall and Whelan, reported in a short abstract published in the proceedings of a conference that they had performed thermal simulations and the results "... *are in general agreement with paleotemperature data from fluid inclusions and isotopic compositions of secondary calcite at Yucca Mountain.*" The purported success of the simulation appeared to lend strong support to the USGS model yet no technical results of the simulations were reported, thus the announced simulations evaded technical review and evaluation by anyone else. As will be shown below, the claims of the USGS researchers turned out to be false.

1/25/2000

On January 25-26, 2000 the NWTRB met in Las Vegas to hear an update from the DOE on the status of studies, including the fluid inclusion research, being conducted by the UNLV Thermochronology Project researchers. In advance of the meeting Attorney General Frankie Sue Del Papa transmitted reports prepared by Dr. Dublyansky to the Board with the request that the Board reconsider the low priority which it gave to the upwelling issue and to give the issue utmost priority in view of preliminary results from the UNLV Thermochronology Project that suggested hot water deposition of secondary minerals. She cited the 1996 USGS age dating of similar deposits with groupings of ages of less than 500,000 years as indicating the secondary minerals are geologically young. Jerry Szymanski submitted additional materials to the Board at the meeting. On February 14, 2000, William Barnard, Executive Director of the NWTRB advised the Attorney General that the Board had not changed its views and declined her request.

8/2/2000

The Nuclear Waste Technical Review Board met in Carson City to hear and consider presentations concerning, among other things, possible disruptive events that could affect the proposed repository performance. Proposed DOE, NRC, and EPA regulations required a total system performance assessment (TSPA) to evaluate the total Yucca mountain repository system for site recommendation by the Secretary of Energy to the President. It was to include all relevant features, events and processes (FEPs) that could significantly affect repository performance, which included both the probable behavior as well as the effects of potentially disruptive low-probability, high consequence events.

Kathy Gaither, an employee of the Management and Operating Contractor, gave a presentation concerning possible events associated with volcanism, seismicity and structural deformation. She reported that the "hydrologic response to seismicity/faulting" was to be excluded from consideration of FEPs that might require further study based on DOE's determination of a low consequence of a disruptive event from this topic. The issue of postclosure criticality was also excluded. Jerry Szymanski and Attorney Harry Swainston were in attendance and were dismayed by this announcement as it meant that the upwelling of water issue was deemed by the DOE to be of little consequence. Swainston drafted a question from the audience for Gaither which in effect asked whether the DOE's view would change if the joint UNLV Thermochronology Project produced results that "*shows a deep seated hydrothermal origin for the calcite silica deposits in the ESF*" and "*how would this affect the disruptive events PMR for seismicity and faulting*" assuming "*that some of the ages are less than a million years old?*" Abe Van Luik, at the time a Senior Policy Advisor for Performance Assessment with the Yucca Mountain Site Characterization Project Office, answered the question for the DOE. He responded, apparently with some coaching, as follows:

The idea that seismic activity could propel water into and flood the repository has been reviewed by a committee of the National Academy of Sciences, and of course it's been reviewed by our own scientists. It is considered incredible, meaning it has such an extremely low probability that that probability is close to zero. And so it is screened out on the basis of lacking credibility scientifically.

* * *

As to speculating what if what we feel is incredible turns out to be credible, we will face that if that actually is the outcome of that [UNLV] research.

2000

Besides excluding FEPs related to hydrologic response to seismic activity and postclosure criticality, DOE also excluded from the TSPA the "generic" FEP, Hydrothermal Activity. In the DOE analysis/model report entitled "Features, Events and Processes in UZ Flow and Transport" (Houseworth J.E., 2000, ANL-NBS-MB-000001-REV00) the path toward exclusion was charted as follows: 1) significant hydrothermal activity in the Yucca Mountain region have occurred in association with the large-scale Miocene silicic volcanism; 2) silicic volcanism has ended in this part of Nevada some 10-11 Ma ago, and its recurrence within the regulatory time frame is highly unlikely; therefore 3) the recurrence of the associated significant hydrothermal activity is equally unlikely. This line of reasoning lead the DOE to the conclusion that hydrothermal activity can be excluded from consideration on the basis of a low probability of occurrence.

It is apparent that the reasoning presented above contains one important assumption, without which the exclusion of the FEP would not be possible. DOE implicitly assumed that hydrothermal activity is always causally related to magmatism in that the magmatic bodies supply the heat for hydrothermal activity. If the assumption is rejected, the DOE's reasoning presented above would not lead to the exclusion of the hydrothermal activity because it would not preclude other types of hydrothermal activity which are unrelated to magmatism.

The assumption is not stated in the DOE report; it appears in the form of a postulate, the veracity of which is never discussed. More importantly, the assumption is false. Hydrothermal systems, unrelated to the magmatic heat sources, are well known around the world. Yucca Mountain is located within the Basin and Range region within which the majority of known geothermal systems does not show any evidence of crustal magmatic heat sources, but rely on the deep circulation of groundwater instead. There is no scientifically sound reason, therefore, to restrict the meaning of hydrothermal activity exclusively to those systems for which the heat is supplied by magmatic sources.

Besides the inappropriate definition of hydrothermal activity, the screening argument of DOE contained information that is flatly misleading. Specifically, the report asserted that calcite, opal and zeolites developed in lithophysae and small veins are of deuteritic origin (i.e., related to initial cooling of ash-flow tuffs), and that many of these deuteritic minerals have fluid inclusions indicating elevated temperatures. Deuteritic or vapor-phase alteration minerals are known to form "selvages" in lithophysae and some open fractures at Yucca Mountain. They comprise the dominant trydimite and feldspar; calcite and opal have not been reported among those minerals. The vapor-phase minerals were formed during compaction and devolatilization of the freshly deposited ash-flow. To the best of our knowledge, fluid inclusions "indicating elevated temperatures" have not been observed in those minerals at Yucca Mountain. By contrast, the extensive fluid inclusion record, which indicate paleo temperatures as high as 80-90°C, has been obtained from calcite, occurring along with opal,

chalcedony, quartz, fluorite and zeolites in lithophysal cavities and open fractures (Dublyansky et al., 2001; Whelan et al., 2002; Wilson et al., 2003). The latter mineral assemblage, however, is definitely not deuteric: on the basis of radiometric dating it post-dates the deposition of the host ash-flow tuffs by millions of years (Paces et al., 1996; Neymark et al., 2002; Wilson et al., 2003).

11/14/2000

On November 14, 2000 at an afternoon session of the Geological Society of America (GSA) meeting at Reno, Nevada, Drs. Jean Cline and Nick Wilson presented the first publicly disclosed results of the UNLV Thermochronology Project. On the same day an article based on an interview with Jean Cline was published in the Las Vegas Sun written by Mary Manning, a reporter for the newspaper. The concerned scientists were surprised and dismayed by the content of the article as it contained quotes and conclusions attributed to Jean Cline, which were factually and scientifically incorrect. Furthermore, it was misleading insofar as it suggested that the scientific debate over the upwelling of water issue was over and the DOE's position that the proposed repository was unlikely to be subject to intrusions of groundwater in the future was correct. The article asserted that the results of the Thermochronology Project reported by Cline and Wilson supported the DOE and USGS claim that the site is "*dry enough to bury 77,000 tons of spent nuclear fuel and defense (nuclear) wastes.*" A quote attributed to Bob Loux, the Executive Director of the Nevada Nuclear Waste Project Office, was equally troublesome. The article suggested that even Loux accepted the claims in the article and that his office would pursue "*other scientific questions about the mountain's stability*" other than the upwelling of water issue. In fact that has proven to be the case.

Many important facts produced during the UNLV Thermochronology Project have been disregarded. For instance, the salinity of the fluid in the two phase inclusions was very high, typical of groundwater originating from considerable depth and uncharacteristic of percolating rainwater. There was a documented presence of calcite and quartz, as well as minerals such as fluorite, commonly associated with low temperature hydrothermal mineralization. Most importantly, however, the UNLV researchers failed to explain the origin of elevated temperatures of ancient waters (up to 65-70°C), determined unequivocally in several dozens of samples. These temperatures effectively debunked a hypothesis rigidly adhered to by the USGS for many years that the deposits were caused by cool rainwater. Without meaningful explanations, these temperatures appeared to be flatly incompatible with the DOE-USGS-UNLV "rainwater" interpretation.

Almost immediately after it became untenable for the USGS scientists to ignore the fact that the deposits being studied were formed by hot water, they scrambled for an explanation other than that proposed by the upwelling hypothesis. They fixed upon an explanation which envisioned a source of heat emanating from a magma body beneath the Timber Mountain caldera which they hypothesized kept Yucca Mountain hot for many millions of years. Undisclosed to the other participants in the UNLV study, they began modeling studies to support their hypothesis.

At the Reno meeting the USGS publicly announced their "hot mountain" hypothesis. They described a theoretical calculation they used to predict the thermal history of the rocks surrounding the high temperature magma chamber producing the volcanism beneath the Timber Mountain caldera. They assumed that the process of heat transfer was limited by conduction. Their own modeling studies of 2001 proved that the mechanism they were espousing was not possible. They neglected, however, to inform the scientific community of this development. The failure of the USGS thermal simulations to reproduce the temperatures measured at Yucca Mountain was made public only in 2004 in a report by Bechtel SAIC Company, LLC, a DOE contractor.

The report was prepared in response to some very pointed questions, posed in 2001 by NRC staff, directed to the issue of the origin of the heat which may have caused the elevated temperature of the fluids which produced the secondary minerals in the ESF. This belated disclosure revealed the selective nondisclosure in the interim by the USGS scientists of important technical information, which implies nothing less than intentional misrepresentation. The USGS scientists continued to tout their hot mountain hypothesis in the years following 2000 in symposia and conferences. They violated their solemn duty to inform the federal decision makers in the DOE, which informed the President and ultimately the Congress that Yucca Mountain was suitable for development as a repository.

A paper delivered at the Reno, meeting of the GSA by Mary Beth Gray, a scientist from Bucknell University, and her co-workers at the Center for Nuclear Waste Regulatory Analysis (CNWRA), described a class of faults (Class B) at Yucca Mountain which contained up to 65 % coarse-grained (crystalline) calcite with two phase inclusions and mechanical crystal twinning, with the latter "*indicative of deformation at elevated temperatures,*" as high as 150°C. The presence of these deposits and the sharp differences in comparison to the calcite mineralization in lithophysal cavities showed that the thermal and hydrologic history of Yucca Mountain was complex and polygenic. During a question and answer period Gray agreed that seismic pumping of groundwater could have transported water through the intensely fractured fault zones and deposited the coarse-grained calcite in the faults.

1/8/2001

On January 8, 2001, the NRC and DOE staffs met for the purpose of an exchange of information by the DOE regarding the treatment of FEP issue 1.2.06.00 (Hydrothermal activity) during the Thermal Effects of Flow (TEF) Key Technical Issue Technical Exchange. DOE had screened out the FEP (Feature, Event, Process) "Hydrothermal activity" from consideration. Because of this exclusion, the DOE assumed it had acquired the "right" not to consider hydrothermal activity in the Total System Performance Assessment. NRC required that the DOE provide a more thorough justification of this screening decision. In particular the NRC staff wanted additional documentation regarding the conductive cooling model of the Timber Mountain Caldera magma body presented by Brian Marshall at the Geological Society of America meeting in Reno on November 14, 2000 (USGS "hot mountain" hypothesis) or to provide an independent model that would explain elevated temperatures in the unsaturated zone of Yucca Mountain from about 12 Ma to 2 Ma. Other specific items related to this issue were requested. In addition the NRC staff wanted DOE to address the timing and mode of formation of secondary mineralization for the Type B faults which recorded elevated temperatures as presented by Mary Beth Gray at the GSA meeting in Reno on November 14, 2000. DOE was asked to explain the apparent saturated conditions of mineralization in the Class B faults. A response to these comments was not finally provided until 2004. DOE's response to the NRC request was published as Appendix H "Analog and Geochemical Evidence for Yucca Mountain Thermal-Hydrothermal History" to the Technical Basis Document No. 2: Unsaturated Zone Flow by Bechtel, SAIC. This appears to be the only publication in which technical details of the USGS modeling were provided. The Bechtel document demonstrated that the results of thermal simulations carried out by the USGS failed to reproduce the temperatures measured at Yucca Mountain and, therefore failed to support the USGS "hot mountain" model. (See further discussion of this disclosure in that time frame, 2004 and 2005, *infra*.)

The FEP 1.2.06.00 issue was different from, although related to, the issue of the hydrologic response to seismic activity, FEP 1.2.10.01.00, which also had been excluded from further consideration. (See discussion of August 2, 2000 meeting of the NWTRB, *supra*).

5/9/2001 The NWTRB met on May 9, 2001 and reviewed the data compiled during the UNLV Thermochemistry Project. Several Board members raised a number of questions which to that date had not been resolved. Among those were questions concerning the source of magnesium found in samples of secondary minerals which had been studied, the source of hydrocarbons in the gaseous inclusions, an explanation for the high salinities in the fluids of the fluid inclusions, the propriety of using a constant lead correction for uranium-lead age dating and any thermodynamic limitations to the rainwater hypothesis. These questions have never been answered.

1/2002 In early 2002 a two-part report entitled "Thermochemical Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 1, Secondary Mineral Paragenesis and Geochemistry" (Wilson and Cline) and "Thermochemical Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada; Part 2, Fluid Inclusion Analyses and U-Pb Dating" (Wilson, Cline, and Amelin) was sent by Dr. Jean Cline of the University of Nevada at Las Vegas to Russell Dyer, a DOE employee. Russell Dyer was the Project Manager in charge of the Yucca Mountain Project in the DOE's offices in Las Vegas. Dyer cited the contents of the UNLV reports in a letter written to Dr. Jared Cohon, the Chairman of the Nuclear Waste Technical Review Board dated January 24, 2002. According to Dyer, Dr. Cline and her colleagues offered conclusions concerning the suitability of the Yucca Mountain site.

Dyer stated in his letter to Dr. Cohon: *"The data collected by both DOE and UNLV researchers confirm that the conceptual model of descending percolation is correct."* He noted that researchers for the State of Nevada disagreed with the descending percolation conclusion. In fact, Dr. Yuri Dublyansky and Jerry Szymanski continued to support a conceptual model based upon their analysis of the data which confirmed that the vadose zone beneath the surface of Yucca Mountain was episodically subjected to an upward flow of hydrothermal, gas-charged water, the upwelling waters concept. Despite this continuing unresolved scientific dispute, Russell Dyer, apparently relying on Dr. Cline's report, advised Dr. Cohon that *"the 'upwelling waters' or 'seismic pumping' hypothesis for the origin of secondary mineralization at the Yucca Mountain site have been adequately addressed and may be discounted."*

Oddly, Dyer suggested in his letter to Dr. Cohon that the State of Nevada concurred in the conclusion that the issue was resolved. Bob Loux verbally agreed with this analysis in at least one conversation with Attorney Swainston, but no written verification has ever surfaced although a written communication continues to be referred to.

3/11/2002 In a subsequent letter from Dr. Cohon to Lake Barrett, Acting Director of OCRWM, dated March 11, 2002, Dr. Cohon cited the Russell Dyer letter of January 24, 2002 and stated that the *"Board concurs with the DOE's conclusions and considers this issue resolved."* Referring to the NWTRB meeting held on January 29-30, 2002 at Pahrump, Nevada Dr. Cohon stated that: *"At the Board meeting and in a letter to the Board dated January 24, 2002, the DOE concluded that the hypotheses of hydrothermal upwelling proposed by Mr. Jerry Szymanski had been adequately addressed and may be discounted. These conclusions were based on the DOE's positive response to a Board recommendation that a joint federal-State of Nevada project be conducted to determine the ages of fluid inclusions at Yucca Mountain."*

Dr. Dublyansky was dismayed that Dr. Cline released her report without first having provided a copy to other participants of the UNLV Thermochemistry Project for review and comment. Any conclusions emanating from the State of Nevada-UNLV-

DOE cooperative study was not supposed to be issued without a consensus of the participants. Dr. Dublyansky was the State of Nevada's representative in the joint study. Dr. Cline maintained that it was not part of her role to draw conclusions from the data, yet she provided enough by way of conclusions to satisfy the NWTRB and the DOE. These conclusions provided the basis for important governmental decisions affecting the lives of countless people.

Dr. Cline's report and the data base upon which it was based were not made available to Dr. Dublyansky, despite repeated requests, until after it was publicly released at the end of May 2002 even though the report was a public document at the time it was sent to Russell Dyer.

Notwithstanding the clear message established by their own data, the UNLV researchers, Drs. Nick Wilson and Jean Cline, remained silent as to the origin of the depositing fluids. The researcher's reticence failed to advise Congress of DOE's failed attempt to demonstrate Yucca Mountain's suitability as a solution to the Nation's accumulating spent nuclear fuel problem.

The results and conclusions of the UNLV studies were published in 2003 in a professional journal, *Geochimica et Cosmochimica Acta* (Pergamon). Interpretations provided in the paper and its conclusions appeared to be so questionable, that Dr. Dublyansky and his colleagues from the Russian Academy of Sciences felt compelled to rebut them. Their critical comments addressing the shortcomings and inconsistencies in interpretation of the data by the UNLV team has been published in *Geochimica et Cosmochimica Acta* in 2005 along with the response of Wilson and Cline.

- 6/26/2002 TRAC-NA delivered a computer disc copy of a 688 page monograph to the Nevada Attorney General in fulfillment of the contract entered into two years earlier to prepare a comprehensive document memorializing the evidence in support of the State's best case with respect to the upwelling of water issue.
- 9/10/2002 On September 10, 2002 the NWTRB held a meeting at the Alexis Park Hotel in Las Vegas, Nevada. Dr. Jared Cohon gave a recap of accomplishments in anticipation of his departure as Chairman of the NWTRB. He stated, in part, that:

Proving something not to be true is the hardest thing to do in science, and a decidedly unglamorous undertaking. Yet, the Board did not shy away from the challenge presented by the hypothesis of geothermal upwelling. I think we did a very effective job in marshalling limited resources and helping to spawn reviews of what was a very complicated and controversial issue.

The concerned scientists did not share Dr. Cohon's self-serving views. The issue may have been adjudged politically resolved as far as the Board and DOE were concerned, but it is far from being resolved for the purposes of the licensing process before the Nuclear Regulatory Commission and subsequent review by the courts.

- 10/27/2003 On October 27, 2003 Attorney Swainston wrote to Dr. Michael Corradini, Chairman of the Nuclear Waste Technical Review Board. He cited the January 24, 2002 letter from Russell Dyer to NWTRB Chairman Jared Cohon as demonstrating a lack of consensus with respect to the lingering rainwater-upwelling controversy. He characterized Cohon's response that the issue was resolved as nothing more than a political opinion. From the perspective of sound science nothing had been resolved. He attached to his letter two reports prepared by Dr. Dublyansky and Dr. Sergey Smirnov of the Siberian Branch of the Russian Academy of Sciences United Institute of Geology, Geophysics and Mineralogy. One report was a critical review of the Nick Wilson and Jean Cline two part report of the UNLV Thermochronology Project,

published by the Russian Academy of Sciences. The second report was a commentary on a paper published by USGS researchers J.F. Whelan, J.B. Paces, and Z.E. Peterman entitled "Physical and stable-isotope evidence for formation of secondary calcite and silica in the unsaturated zone, Yucca Mountain" (Applied Geochemistry, Pergamon), which was submitted for publication. Swainston urged an unbiased reconsideration of reasonable interpretations which might be attributed to the data base that had become available and stated that the NWTRB had the statutory mandate to do so. "*It is a dereliction of this duty for the Board to disregard its mandate by leaving contentious issues affecting the performance of the proposed repository left unresolved,*" Swainston wrote. Dr. Corradini acknowledged receipt of the letter and resigned as chairman a short time later. The Board declined to reconsider a review of the upwelling of water issue in a subsequent letter but advised that Dr. Dublyansky should pursue a debate in the technical journals.

In accord with this suggestion, in 2004-2005 Dr. Dublyansky and his colleagues from the Russian Academy of Sciences published critical evaluations of the DOE-USGS-UNLV models in the three professional journals (Applied Geochemistry, Pergamon, 2004; Journal of Contaminant Hydrology, Elsevier, 2005; and Geochimica et Cosmochimica Acta, Pergamon, 2005).

05/ 2004

In May 2004 Bechtel SAIC published Technical Basis Document No. 2: "Unsaturated Zone Flow." In Appendix H to the document, entitled "Analog and Geochemical Evidence for Yucca Mountain Thermal-Hydrothermal History," Bechtel SAIC disclosed that the results of thermal simulations carried out by the USGS researchers failed to reproduce the temperatures measured in the ESF at Yucca Mountain by fluid inclusion studies. Appendix H stated:

Between 10 and 6 Ma, the magnitude and duration of heating predicted by these simulations are less than those recorded by fluid inclusion and stable isotopic data from secondary calcite from Yucca Mountain. [p. H-11]

The largest thermal perturbations are predicted for simulation 14, which includes a prolonged period of magmatism (15 to 11 Ma), the incorporation of a 500-m unsaturated -zone layer with a lower thermal conductivity, the presence of a 2-km thick convection system directly above the magma chamber, and a very shallow (2.5-km-deep) magma chamber. However, for this most extreme case, at 4 km distance from the edge of the magma chamber, a maximum temperature of less than 50°C is predicted, which declines to values less than 40°C at around 9 Ma. Even less heating would be predicted for most of the Yucca Mountain area, as the repository footprint lies approximately 4 to 9 km from the caldera margin. [p. H-10]

It should be noted that the actual location of the ESF-ECRB complex is 7-9 km from the Timber Mountain Caldera so the simulated temperatures would have been substantially lower than that suggested by Appendix H.

The Bechtel SAIC Appendix H postulated four mechanisms that could potentially be invoked to substitute a separate and distinct scenario to provide a source of infiltrating hot water and thereby resolve the problem created by the discrepancy between the USGS simulations and the empirical data:

Possible scenarios that might resolve this discrepancy include: (1) continued injection of magma (without associated volcanic activity) into the shallow crust in the vicinity of the Timber Mountain volcanic center after 11 Ma., (2) intrusion of magma closer to Yucca Mountain area (to the southeast of

the Timber Mountain caldera), (3) lateral subsurface flow of hydrothermal fluids from the Timber Mountain area toward Yucca Mountain, and (4) the presence of additional overburden in the Yucca Mountain area that was subsequently removed by uplift and erosion, which would have resulted in a deeper and hotter environment for the earlier portion of the thermal history of this area. [p. H-19]

None of the scenarios postulated by the DOE through its contractor Bechtel SAIC could resolve the discrepancy without quantitative modeling and subsequent validation of the model's boundary conditions and input parameters. Acceptance of any of them would necessarily lead to a re-evaluation of the current understanding of the geological system of Yucca Mountain established by the twenty years of studies of the site, according to Dr. Dublyansky who has prepared a paper on the problems with the USGS modeling of the thermal regimes at Yucca Mountain.

10/2004

Bechtel SAIC published an analysis/model report: "Features, Events, and Processes in UZ Flow and Transport" (ANL-NBS-MD-000001 REV 03). In the document, Bechtel SAIC documented the decision to exclude from consideration in the Total System Performance Assessment for License Application the FEP Hydrothermal Activity. Justification ("screening argument") of the exclusion relied heavily on the results of the USGS thermal modeling, which were presented the purpose of generally supporting the USGS conductive heating model. The discrepancy between the modeling results and factual data were played down and explained by undiscovered younger magma bodies presumably present in the Yucca Mountain area (scenarios (1) and/or (2) from quotation above).

02/09/2005

In their evaluation of the Bechtel SAIC Appendix H to the Technical Basis Document No.2, the NRC staff rightly noted that none of the scenarios offered in Appendix H is supported by evidence or adequate modeling. Nevertheless, the NRC staff accepted one of the hypothetical mechanisms, (3) lateral subsurface flow of hydrothermal fluids from the Timber Mountain area toward Yucca Mountain, as offering a credible alternative to the discredited "hot mountain" hypothesis. The NRC staff supported its selection of mechanism (3) with the vague statement that such thermal outflows are known elsewhere. This allowed the NRC staff to accept the USGS/DOE conceptual model for secondary mineral deposition in its entirety. Consequently, the NRC staff agreed with the DOE's position that the hydrothermal upwelling FEP could be excluded from consideration in the Total System Performance Assessment for License Application.

PRESENT

Dr. Dublyansky strongly believes and the other concerned scientists support his view that presently, the DOE does not have a plausible explanation for past elevated temperatures in the unsaturated zone of Yucca Mountain. The genetic link between the elevated temperatures of waters that circulated through the unsaturated zone of Yucca Mountain and Miocene silicic magmatism espoused by the USGS cannot be established. Consequently, the origin of the fluids that were responsible for the deposition of the secondary minerals in the unsaturated zone has also not been established and remains an ominous cloud over repository safety and creates doubt over the advisability of proceeding with licensing prior to resolution of the issue.

The exclusion of processes that actually caused the circulation of fluids from detailed consideration and appropriate resolution on the basis of "low probability of occurrence" or "low consequence" raises two possible scenarios:

(A) If the issue is resolved prior to a license application by the DOE, any reference to "exclusion", "low consequence" or "low probability" would be rendered immaterial

by the appropriate treatment (screening) of a FEP, which is part of the Total System Performance Assessment procedure. Even at this late date resolution before licensing might be done outside the formal TSPA procedure.

(B) If the issue is not resolved before licensing it necessarily must be aired during the licensing proceedings. Assurance that the issue will be considered during licensing is guaranteed only if there is a formal inclusion of hydrothermal activity in the TSPA. Inclusion as an FEP raises the full gamut of considerations involving probability and consequences during the licensing proceeding.

The historical record indicates that the treatment of the upwelling of water issue by the DOE, the USGS, the NWTRB, and recently the NRC staff has been deficient at best and ethically corrupt at worst. Other entities, notably the State of Nevada and the affected units of local governments have fared little better. The researchers at UNLV, while expected to be neutral and objective, demonstrated a strong bias for the DOE and USGS position.

The failure by DOE and its contractors to follow the proper scientific method and practices in the course of the Yucca Mountain project with regard to what, in truth, should have been the most pressing safety issue of the proposed Yucca Mountain repository has produced the possibility of two equally undesirable outcomes: (a) Yucca Mountain will be denied a license on scientific grounds. This would mean that billions of ratepayer's dollars would have been wasted and the United States would have to start from scratch the search for a nuclear waste disposal solution. A viable solution to the waste problem could take decades. Although this outcome would be disastrous for the many interests that have placed reliance on the Yucca Mountain solution, it seems to be the only proper alternative. (b) Safety will be compromised and Yucca Mountain will eventually be licensed, developed and loaded. This outcome would mean that planet Earth will host a very dangerous facility, a ticking time bomb. The United States would have abused its leadership and set a terrible precedent for other countries in demonstrating that scientific safety considerations can be disregarded in siting nuclear waste disposal facilities and that sound science in such projects could effectively be neutralized by means of political and managerial manipulations. This may lead to the replication of Yucca Mountain style repositories in other countries to the ultimate detriment of the world community.

The Important Issue - Origin of the Thermal Waters

Virtually all entities that were expected to reach an informed understanding of consequences attending the undisputed fluid inclusion results (NWTRB, DOE, UNLV, USGS) avoided asking and answering the critical question about the **origin** of thermal fluids responsible for deposition of secondary minerals at Yucca Mountain. They concentrated, instead, on physical parameters such as the temperature and the ages of the crystals. Dr. Bodnar in his July, 8, 1998 letter to the NWTRB recommended that the **timing** of hot temperatures must be determined. In the July 24, 1998 letter from Jared Cohon to the DOE the NWTRB recommended to DOE that the **age** of the hot water circulation – not its origin must be determined (*"The Board believes that the ages of fluid inclusions should be determined"*). The UNLV researchers declared their goal to determine depositional temperatures of minerals, their spread within the repository block, and ages – not the origins. That made it possible for Drs. Wilson and Cline, to state that hot fluids were there 5 Ma ago, but not later, so they are of no

consequence for the repository performance. The later conclusion, however, does not follow from the age information alone, in the absence of the knowledge regarding the origin of thermal waters.

According to the NRC guidance (“Yucca Mountain Review Plan, Final Report”. NUREG-1804, Rev. 2, 2003) there exist only three criteria on the basis of which a feature, event or process (FEP) could be excluded from consideration in the performance assessment: 1) the FEP is specifically excluded by regulation; 2) the probability of occurrence of the FEP falls below the regulatory limit (i.e., it is less than 10^{-4} per 10^4 years or 10^{-8} per year); and 3) omission of the FEP does not significantly change the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment. Hydrothermal activity has not been excluded by any regulation. Application of the two remaining criteria is not possible without knowing the origin of the fluid which is responsible for the circulation.

A random process that has occurred only once over the last 10 million years would have the probability of occurrence of 10^{-7} per year, or ten times the regulatory limit. Therefore, if all we know about hydrothermal activity at Yucca Mountain is that it occurred at least once during the life-time of Yucca Mountain (which is, about 12 Ma), it would not be possible to exclude it from consideration on the basis of the “low probability” criterion. Lower probability could be argued if the process is not random but is coupled with another process which is extinct at Yucca Mountain. That was the approach used by USGS and DOE, when they arbitrarily assumed an unique genetic link between elevated temperatures of waters at Yucca Mountain and silicic volcanism (the latter has exceedingly small probability of recurrence). This assumption has been proven to be false by the results of the USGS thermal modeling in 2001.

In order to claim a “low consequence” with regard to hydrothermal activity, the scale of the process, its expected time of occurrence, and many other parameters such as the temperatures of waters, their chemical compositions, composition of dissolved gases, pathways, character of circulation, etc. would have to be known and evaluated through comprehensive modeling. The primary requirement therefore is the knowledge of the **origin** and driving mechanisms of hydrothermal activity; its age would be of secondary importance.

According to the DOE, the thick unsaturated zone at Yucca Mountain formed 11.6 Ma ago. The lift of thermal water from the water table to the level of the repository zone, be it 5-7 Ma ago or more recently requires an explanation. An explanation for the movement of hot water through the vadose zone 6 Ma ago, for instance, would necessarily entail an acceptance of Jerry Szymanski’s mechanisms or the need to propose a meaningful alternative. In either case the continued viability of the Yucca Mountain project would be jeopardized.

The preoccupation of the entities involved in studies of secondary minerals at Yucca Mountain with secondary parameters, such as ages¹, temperatures, etc. and their studious avoidance of the central question of the origin of hydrothermal activity is troubling.

The conscious choice to avoid the critical question concerning the origin of the thermal fluids appears grounded in an agency policy to keep the Yucca Mountain project alive at any cost. The absurdity of the policy is replete when ranking DOE managers repeatedly proclaimed that "*sound science will prevail.*" For the federal agencies involved, the policy is nothing more than a management tool, but one that the scientists that work for the USGS and UNLV readily embraced.

¹ Given the DOE's preoccupation with the ages of the deposits, the question arises whether the age determinations were accurate and whether the methodologies used for the age dating were appropriate. A discussion of the age dating problems is omitted from this document as it would unnecessarily detract from the central issue which is the origin of the fluids. Suffice it to say that Drs. S. Pashenko and Y. Dublyansky from Russian Academy of Sciences have demonstrated that the ages reported by Drs. Wilson and Cline (between 11 Ma and 1.9 Ma) may be in error by millions of years.