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WARREN A. BISHOP
Chair

STATE OF WASHINGTON

NUCLEAR WASTE BOARD

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MINUTES OF JOINT NUCLEAR WASTE BOARD/ ADVISORY COUNCIL MEETING

February 19, 1987

1:30 p.m.
EFSEC Hearings Room
Rowesix, Building #1
4224 Sixth Avenue S.E.
Lacey, Washington 98504

Board Members Present:

Warren A. Bishop, Chair
Allen Fiksdal, EFSEC Designee
Dr. Royston H. Filby, Water Research Center Designee
Philip Johnson, Ecology Department Designee
William Lingley, DNR Alternate Designee
Nancy Kirner, DSHS Designee
Representative Nancy Rust

Advisory Council Members Present:

Phyllis Clausen
Nancy Hovis
Valoria Loveland
Sam Reed
Robert Rose

The meeting was called to order by Warren A. Bishop, Chair.

Mr. Bishop assured persons in the audience that they would have time to ask questions and make comment. He acknowledged that it was difficult for members of the Legislature who are on the Board to attend the afternoon meetings, especially when the meeting is on Thursday afternoon and a Board meeting on Friday. He was certain they reserved their time to attend the Board meeting.

Mr. Bishop explained that the information meetings were held regularly throughout the year for the benefit of Council and Board members. The purpose of the meetings is to discuss these items in public and to provide information on a broad basis to as many persons as possible.

Mr. Bishop said that this afternoon several individuals were invited to discuss natural resources at Hanford. He explained that material handed out contained information regarding the requirements of the Nuclear Waste Policy Act (NWPA) concerning natural resources at potential repository sites. Mr. Bishop said that the office staff, USDOE and contractors had been aware of the potential for the presence of various natural resources at the Hanford site. Mr. Bishop noted that a reference was made to this in the U.S. Nuclear Regulatory Commission's comments on the USDOE's Environmental Assessment, which pointed out that not enough attention had been given in the EA to the question of geothermal resources.

Mr. Bishop called the audiences' attention to a February 17 memo by Charlie Roe which summarized the requirements of the NWPA and the USDOE's guidelines as they relate to natural resources.

Mr. Bishop asked Terry Husseman, Program Director of the Office of Nuclear Waste Management, for additional comment. Mr. Husseman said that the main issue is whether the USDOE Environmental Assessment adequately dealt with the potential for natural resources in the proposed repository area at Hanford. He said that the guidelines and statute say that it is a potential disqualifying condition if there is the potential for development of resources. Mr. Husseman said we need to visualize the area surrounding the potential repository site 10,000 years from now, with no institutional controls whatsoever. After 200 years of institutional control, USDOE assumes that there will be no signs or indications warning someone not to explore for oil, gas, geothermal resources or groundwater "mining".

Mr. Bishop introduced Bill Lingley, Washington State Department of Natural Resources. Mr. Lingley introduced Tim Walsh as the co-author of his study, who also would be answering technical questions. Mr. Lingley said that the DNR Division of Geology has a program to assess the petroleum potential of the state. The program is mandated by the Oil & Gas Conservation Act. The division also administers the Geothermal Resources Act, the Underground Gas Storage Act, and other programs related to petroleum. He joined the department last year, after 13 years in the petroleum industry exploring in basins similar to the Columbia River Basin. Mr. Lingley stated that at the time he joined DNR there was a question about the resources at Hanford, and that Dr. Bill Brewer (Office of Nuclear Waste Management) had suggested that the DNR undertake an assessment of the work that had been done by the USDOE and contractors up to that stage.

Mr. Lingley said that the work that had been done was summarized in a paper by Leaming and Davis, which was an excellent paper but, unfortunately, the petroleum part of the paper was wanting because they only assessed the petroleum potential of the basalt. He noted that basalt which is formed at 1400 degrees C is not normally the province where you

would likely find petroleum. He noted that Dr. Brewer brought this up and the USDOE responded by hiring a consultant who has worked with the DNR Geology division in the past. The DNR wrote a critical letter and some of the Rockwell technical staff said that if the state were going to be critical it should come up with something on its own. Hence, this is the work that he and Mr. Walsh would be presenting.

Mr. Lingley presented a slide which described the disqualifiers for natural resources. He said that when most of us think about the natural resource issue, we think about the public interest and whether the value of natural resources (i.e., petroleum) outweigh the potential benefit of Hanford as a repository for nuclear waste. The statutory issues are related to the integrity of the repository itself. He said, can breaching by drilling directly into the repository hinder its integrity? or can breaching occur by exposing the repository to drilling? In one scenario, an oil and gas test might be drilled at some time in the distant future when there is no prohibition and hazard warning systems were not in effect, and could one drill directly into one of the canisters, or into the repository? Rockwell did a study on this which was a good piece of work. If you consider oil and gas drilling, the total-depth diameter of a typical borehole is 8-1/2". If you consider the size of the repository chamber itself and the canisters, the probability of an 8-1/2" drill entering a canister are vanishingly small, according to Mr. Lingley.

The more likely scenario, and a scenario which unfortunately may already be occurring, is exposing the repository to formation fluids and drilling fluids. Mr. Lingley said that if a well is drilled into a aquifer at a greater depth, because the aquifer is at greater depth, the pressure is that much higher and fluids are driven out of the aquifer and up into the fractures which are contiguous with the repository chamber. Mr. Lingley said that the integrity of the Hanford repository is dependent on the fracture filling minerals. Basalt, he said, is a rock that is inherently very permeable but not particularly porous. It's not a good place to store oil and gas, but it has an excellent ability to transmit fluids, said Mr. Lingley. The division has been led to believe that Hanford has fracture filling minerals. However, petroleum geologists say that fracture filling minerals are present only for a while, and that they can be dissolved or opened and closed over time. This, according to Mr. Lingley, is the model of the greatest concern to geologist.

(For the rest of Mr. Lingley's and Mr. Walsh's presentation, please refer to their report: "Issues Relating to Petroleum Drilling Near the Proposed High-Level Nuclear Waste Repository at Hanford", enclosed.)

After Mr. Lingley completed his presentation, Mr. Bishop introduced Curtis Canard of the Council of Energy Resources Tribes (CERT) to make his presentation. Charlie Roe interrupted and asked Mr. Bishop if he could inquire about leased state-owned lands for oil exploration. Mr. Bishop agreed, and Mr. Lingley responded that several parcels were bid for by Shell Oil Company near the RRL at Hanford. He said that the major companies with interest in the basin were Shell, Amoco, Exxon, Chevron, American Hunter, Arco, Tyrex and G.B. Howell. He said there was a very aggressive and sincere level of exploration.

Mr. Lingley said that Shell, Chevron and Exxon were the dominant companies for leasing. Mr. Roe asked what the average oil exploration lease amount was right now per acre. Mr. Lingley said in the last year, the lease high has been $40 per acre, and the low was $2 per acre; the average was about $13 per acre. Mr. Lingley said that much exploration has been near the Saddle Mountains and compared this to the Powder River Basin.

He said the Teapot Dome and Salt Creek Fields were located in the central part of that basin, and he estimated that the total reserves for the Powder River Basin would be (in natural gas equivalent) perhaps 30 trillion cubic feet. Council member Sam Reed asked Mr. Lingley if there was potential for oil exploration. Mr. Lingley said that they had not evaluated the eastern half of the basin, and so they did not have geochemical data to assess that part of the basin. However, they have seen data that indicated a potential for oil. Mr. Reed then asked if drilling was temporarily suspended in the Gulf and other areas of the country. Lingley said the "rig" count was half of what it was two years ago. He said it was the severest recession for the industry since 1958. Mr. Reed asked if the companies anticipated price increases, and Mr. Lingley responded that price wouldn't really matter that much if a company could tap into 30 trillion cubic feet of natural gas.

Dr. Roy Filby asked if the oil versus gas resource decision was based purely at this moment on geochemical data. Mr. Lingley said that was right, the liquids recovered at this time are a gas condensate. Dr. Filby also asked, assuming there were mostly gas deposits in this region, whether this would rule out a repository site here. Mr. Lingley said it would not.

Mr. Bishop introduced Curtis Canard, and said that we would get back to those with additional questions.

Curtis Canard said he was from the Council of Energy Resource Tribes (CERT), from Colorado, representing the Umatilla and Nez Perce Tribes.

He had been the on-site representative for the two tribes since May. He met with USDOE, NRC and Washington State to do some background work on regional geology. He was a petroleum geologist who worked for Exxon for 18 years. He said things in Washington State were reverse of what the industry was experiencing elsewhere. In Washington State everything is up, whereas drilling, etc. was depressed in the rest of the nation.

Mr. Canard showed a slide cross section of the basalt at Hanford based on deep wells drilled. He said Shell Oil Company's #1-29 Bissa Well was drilled north of the Yakima Firing Range. He said after drilling about 4000 feet into the basalt they ran into coal seaMs. He said as they kept drilling they reached sands, shales and clays and started to find "gas shows" in the sands. They found Cretaceous sediments and bottomed the well at 15,000 feet in granite. On the surface, he said, they found a fault to the east. Further east is the Columbia River and a Shell Oil well near Saddle Mountain which was drilled to 11,500 feet. In the sediments and they found coal again. This well bottomed at 17,500 feet. Some sandstone is found at 13,300 feet, which produced high quality gas and condensate. On the surface on the north side of the Saddle Mountain anticline there is a fault zone. Farther south is the repository location between two ridges. They are not sure what happens in the subsurface here. Farther south still is Rattlesnake Mountain. Here there is a well drilled by Chevron in the mid-1950s. Mr. Canard said that they found sediment and coal samples in this well. He said they also had problems with blowouts when the well was drilled. They also lost circulation which happens if you're in an area with highly fractured basalt. Two more wells were drilled and a dipmeter was run down into one of the wells. The dipmeter recorded extreme drips in the well, which is interpreted to mean fault zones.

He said there were many questions regarding faults in the subsurface. He said it is a guess as to what is at Hanford in the subsurface, because there are no deep wells beyond 5000 feet on the site. He said this was his interpretation, and hoped they could get a better handle on

it in the future. This completed Mr. Canard's presentation.

Mr. Bishop said Mr. Canard could answer questions. There was some discussion as to how the natural gas came to be in the area mentioned by Mr. Canard. Mr. Bishop then introduced Dr. Bill Brewer who said that our Office had been in touch with the Bureau of Land Management (BLM), Portland Office, which had corresponded with various agencies over the possibility of opening up parts of Hanford for exploration. He referred to two letters from the Department of Energy to the BLM, which in effect veto the industry applications for drilling on the reservation. He said there also was a list of about 80 companies that had applied in recent years and been turned down by the USDOE. Dr. Brewer said that the industry desire to get on the reservation is very real, even though things are very bad in the rest of the country for exploration.

Mr. Sam Reed asked what risk drilling holes would have to the operation of a repository. Mr. Lingley answered that it was difficult to assess. He said that a number of holes already have been drilled for research on the site, and that some would be plugged with cement. The probability of the holes affecting the repository would be low, but that it still was a statutory disqualifier and that we must attempt to assess that possibility. Mr. Reed asked how the exploratory holes are usually left. Mr. Lingley responded that they usually are isolated with cement plugs. Mr. Reed asked if there was any data on the integrity of the plugs over extended periods of time. Mr. Lingley answered generally that there was no data on this, but that cement contained calcium carbonate and if you put acid on it it fizzes, or dissolves.

There was some discussion about whether the holes last "forever" in the basalts, or whether they "heal" eventually. Mr. Lingley said that in basalt it would be more likely that the holes would not heal.

Mr. Husseman mentioned that in the letters from the USDOE to the Department of Interior turning down requests for exploration, the USDOE indicated that Hanford was still under serious consideration for the location of a repository and that the USDOE is unwilling to approve the drilling of holes, either on or off site, which conceivably could affect the aquifer or deep geological structures on the site.

Mr. Reed asked if the drilling of a number of new test holes on the site would add something to the knowledge that is necessary to deal with the repository. He asked if they could characterize the information they produced. Dr. Brewer answered that to some extent that would be helpful, if you could do some hydrologic testing and make a deal between the repository operators and commercial operators. He said that information on the stratigraphy would always be useful.

Mr. Reed asked if greater depth would provide greater information, and Dr. Brewer said that the greater depth wells could provide useful data. Mr. Lingley said that they explored this question and that the data received would not offset USDOE's extreme cost of drilling. However, he said, if oil companies were drilling it would be a good way to gain a lot of data (if the companies had an economic incentive).

There was some discussion about the seismic data that could be acquired, and Mr. Lingley said that present data USDOE has is "old generation" and that it would be helpful to have new seismic studies. They are also surprised that the USDOE hasn't aggressively acquired this information already.

Don Provost said that in earlier discussions with NRC, the NRC wanted to determine the "basement" of the repository and that the area is saturated with

natural gas in the water. He said that the natural gas in the water is being used as a tracer to determine where the water flows now. He said that the reason for the site disqualifier on natural resources is that someone 200 years from now could come in and explore the area. Mr. Provost said it was not trying to balance today's need for energy with the geology of the area, you must look at what might happen if someone were exploring 200 years from now.

Dr. Filby said that probably future seismic programs could identify the repository area immediately. Mr. Provost said that philosophy behind the guidelines is that there would not be that ability.

Mr. Reed asked what access the state had to data produced by the commercial exploratory operations. Under the Oil and Gas Conservation Act, Mr. Lingley said well logs and other data were required. This data must be kept confidential for one year, but Mr. Lingley said that the data is publicly available now for the Shell wells. He said that much of the data is of extremely high quality.

Mr. Reed wondered if there was any data that was not available to the state that might have potential as far as the repository location was concerned. Mr. Lingley said that seismic data would be valuable. He said that the private companies may be willing to sell the data, but he doubted it. Mr. Lingley said that he and Dr. Brewer had discussed joint seismic profiles with Shell and Chevron across the Reservation which would be partially funded for repository research and partially to complete the tectonics picture for the oil companies.

Dr. Brewer said he wanted to follow-up Dr. Filby's comment on future identification of the repository. Dr. Brewer said that future investigators would likely identify the repository. But, Dr. Brewer said, the reason we're having this special session this afternoon is because of a peculiarity in the Act which states that if there is a natural resource under the site, and future generations would explore for it, then it is an automatic disqualifier. Dr. Brewer said that it was a tough part of the Act and that was why we were discussing the resources this afternoon.

Mr. Bishop opened the meeting to public comment. Mr. Ray Issacson asked to comment. He wondered if the sandstones and clays were consistent under the basalt, and if Mr. Lingley had data to support this. Mr. Lingley said that he would say there is sandstone and clay under the basalt fairly uniformly--but that he did not have data to say whether it was uniformly blanketed under the repository location and the rest of the site.

The discussion continued between Mr. Issacson and Mr. Lingley, with Mr. Lingley citing other studies he had done of a similar nature. Mr. Issacson asked about products of the reaction of the groundwater within the basalts. Mr. Lingley said that some products were inert, some were soluble, and that the Rockwell and USDOE studies did a pretty good job of describing these products. The discussion continued about pH and minerals in the basalt waters, and rates of groundwater movement in the basalts.

Following this technical discussion, Mr. Issacson inquired as to the types of natural gases located, and whether there was any other type of gas besides methane which is a "swamp gas". Mr. Lingley said that the gas was primarily methane, but that methane was not "swamp gas". Both Mr. Lingley and Mr. Issacson agreed on the formation of methane and discussed the types of gases further. Apparently, according to Mr. Lingley, Rockwell is studying the different types of gas. Mr. Issacson wondered how many wells were being drilled at this time, and Mr. Lingley answered that no wells were being drilled at this

time, but that DNR has issued one permit. The discussion continued, with Mr. Lingley describing different types of plugs for wells that may be used, and Mr. Issacson said that the wells' effect on the repository should be reviewed as a major part of the review program. The discussion changed to natural gas prices which are at an all time low, and the trouble with drilling for natural gas and not having the resource pay for the cost of excavating it. Mr. Issacson said he was concerned about having an affordable source of energy for those with lower incomes. Mr. Issacson continued by asking several technical questions of Dr. Brewer and Mr. Canard regarding the dipmeter survey in the wells and the angle it disclosed in the basalts. The conversation followed along technical lines regarding well-depth exploration and materials underlying the basalts.

Mr. Issacson completed his questions, and Mr. Bishop asked for the next question. Marie Harris, Bacon & Hunt, asked if the drilling would disrupt the groundwater system and if it would be difficult to get groundwater travel times. Mr. Lingley responded that it is difficult to tell if the exploration shafts would disrupt the groundwater studies, but that the existing wells probably would not disrupt groundwater flows. Ms. Harris also asked if the wells were plugged, if this would disrupt the groundwater. Mr. Lingley said it would depend on how sophisticated the plugging methods were.

A citizen, P.J. Kisor, questioned if the hills were the areas where hydrocarbons were most likely to be found. Mr. Lingley said no, at the near surface there were traps for hydrocarbons, but a fault may or may not be a trap. There are a lot of different possible traps, and the most likely trap would be where the faults were, or where the ground was pushed up, according to Mr. Lingley. The discussion with Mr. Kisor continued regarding where the wells were drilled.

Mr. Bishop asked Dr. Bill Brewer to introduce Mr. Gordon Bloomquist from the Washington State Energy Office. Mr. Bloomquist is the Energy Office's specialist in geothermal resources. The state of Washington is beginning to make use of geothermal resources and, therefore, the Energy Office has the responsibility in this area. Dr. Brewer said that the Yakima jail used geothermal energy; geothermal energy is one of the resources under consideration.

Mr. Bloomquist said he would review what geothermal is, what it is used for and what is known about the Columbia Basin, and to focus on geothermal applications. Mr. Bloomquist (using slides) said that the DNR takes the lead in exploration of geothermal resources, and that the Energy Office focuses on the commercialization of the resource, such as looking at electrical generation and other uses of the resource.

In Washington State, Mr. Bloomquist said, a third partner is the Department of Ecology. By definition in state statute, geothermal resources are hot waters that could produce electricity. So, according to Mr. Bloomquist, any hot water that doesn't produce electricity is considered groundwater and is covered by the Department of Ecology. He said that geothermal resources begin at 4 degrees or 5 degrees C or 40 degrees F, and others figure a more appropriate cutoff temperature would be 300 degrees F. He said that we know very little about geothermal resources in the Northwest. The first major drilling for geothermal was done at Britenbush Hotsprings in the Cascades in about 1983. However, he said that drilling in Canada and Oregon encountered geothermal sources that were much hotter than the sources found in the Washington Cascades, so they do know that there is a major resource in the Cascades. He explained that high levels of heat below the surface exist all around us, in California and of course Yellowstone National Park. He said that as hot temperatures pass through rocks

some of the minerals have changed colors. He said some of the major focus of hydrothermal mineralogy has been done at Mt. Adams, which has shown a possibility of a major resource.

Mr. Bloomquist said that the geothermal potential in the world follows the edges of the continental plates. A lot of geothermal activity is in Iceland and New Zealand, Japan and Italy. That would mean the western U.S. and down into Mexico also is extremely active. He said the majority of the Columbia Basin also shows geothermal activity. He indicated areas of geothermal activity on a map done in 1980 by the DNR and Oregon Institute of Technology. He said temperatures and gradients were determined at that time in wells they had records for. The Cascades showed a high temperature range and the Columbia Basin showed a low temperature resource area, generally characterized by wells ranging from 80 degrees to 110 degrees F. at depths of less than 2000 feet. He said that on a worldwide basis, temperature increases with depth per km by about 25 degrees C. At the Columbia River Basin this increases to about 37 degrees per km. Mr. Bloomquist said a well was drilled in the Yakima area confirmed this gradient to about 18,000 feet.

Mr. Bloomquist said a major example of geothermal resources was when Mt. St. Helen blew up, even though some shallow drilling had shown that there didn't seem to be any excess heat in Mt. St. Helens. He said this shows that, in the Cascades, depths of 2000 to 4000 feet must be reached to locate the geothermal resources at high temperatures, deeper than the surface groundwater. He said that in the eastern part of the state there are very few indications of geothermal energy except in wells that have been drilled. In the Yakima area there is a well drilled in the early 1900s, used at a car wash, with water ranging from 86 degrees to 90 degrees F. In 1985, he said, the Yakima Jail started using a geothermal system for a 265 bed jail (heated geothermally with a heat pump system). He said groundwater forming the geothermal resource is heated by magma close to the surface; it runs down into faults and come back up again as springs or as geysers.

He said that they really don't know why the heat is in the Columbia Basin. Several theories conclude that there is a thinning of the earth's crust in that area, forming a high temperate region. He said that in the Columbia Basin we are not likely to find the high temperatures which will produce steam to produce electricity. But in the Cascades it was a different story and that a production well at Newberry Volcano is slated to be drilled about a year from now.

Mr. Bloomquist said a number of applications of geothermal energy included agricultural uses, electricity, etc. He said electrical generation has used water down to about 190 degrees F. or less. This puts us into a range now where we can look at the Columbia Basin for electricity generation. Mr. Bloomquist said there are three or four uses of the resource in the basin such as use in textiles, foods, agriculture, minerals, and as a secondary recovery technique to recover oil.

Mr. Bloomquist said another use would be to "cascade" the resource from industrial use to home heating and agriculture production. Oregon's Institute of Technology campus has been heated geothermally since 1964. It is a very cost effective system. He showed a slide of the heat exchange system at the Oregon campus where they have wells which go down to about 1500 to 1800 feet. They pull up water which is about 192 degrees F. The water goes through a heat exchanger and then a circulating system.

He said that the Capitol in Boise, Idaho was heated with water at about 162 degrees, which Mr. Bloomquist said is water of higher temperature than at Hanford. He said that a heat pump works like a refrigerator only opposite--

using electricity to drive a compressor which extracts the energy from the geothermal resource and boosts the temperature to a usable level. He demonstrated other systems in use, such as a turbo compressor which allows you to boost even lower temperature waters to a very high level. He said the city of Ephrata in Eastern Washington is using a geothermal system which replaced their former heat system, which cost $22,000 per year. The Grant County Courthouse (in Ephrata) electric bills are now $2,000 per year. (The Courthouse and Courthouse Annex and some residential housing use this system.)

He proceeded to discuss various other systems where geothermal resources are in use, such as agriculture, aquaculture, and greenhouses.

In searching for geothermal resources, Mr. Bloomquist said they follow pretty much the same steps as the oil and gas production companies in seismic and mineral studies, and magnetic surveys. However, he said, the best way to find out is to drill a well. He said it often is good to use existing wells to start, and measure water pressures. He said a major study the Energy Office did last year for the Bonneville Power Administration was available from his office, called the "Pink Report". He proceeded to describe various technical aspects of examining the groundwater and reviewed the application of it in heating systeMs. He said in the Columbia River Basin, a binary system plant would be needed to boost the lower temperatures up enough to create steam for electricity. Mr. Bloomquist mentioned that there were several systems like this in existence elsewhere. He said in this state, the lower temperature geothermal resources are regulated by the Department of Ecology. Leasing is done by DNR if water temperature is high enough to generate electricity.

Mr. Bloomquist ended his presentation here. Mr. Bishop opened the meeting to questions from the Board and Council

There was a question whether the wells were different than regular water wells, and Mr. Bloomquist said they weren't that different.

The question also was posed whether geothermal resources would be a valuable resource for the future, and Mr. Bloomquist answered of course it was, and also geothermal exploration could disrupt the hydrology more and be a greater threat to radionuclide travel perhaps than oil or gas. He also said that pumping massive amounts of water out would change the flow of the water.

A Board member asked if the water was removed from the ground could it be replaced? Mr. Bloomquist said in many cases prudent operators would reinject the water back into the same aquifer for several reasons. However, it has been difficult in some more shallow wells to replace the water into the aquifer.

Mr. Bishop opened the question period to public.

Mr. Ray Issacson wondered why they would drill at Hanford at all if you need to be close to the population for the most efficient use of the resource. Mr. Bloomquist responded that it could be expensive, but in some cases the expense would be justified.

Mr. Allen Fiksdal, EFSEC Designee, commented that we must remember that we are looking into the future, and the location of cities and populations is apt to change.

There were no further questions or comments.

Mr. Bishop turned the program over the Dr. Bill Brewer. Dr. Brewer's presentation is on groundwater and future agricultural activity as a resource, said Mr. Bishop. Before Dr. Brewer's presentation, however, Mr. Bishop called a short break, and then reconvened.

Dr. Brewer said that groundwater was treated differently in the Act than the other resources. He said you must assume the first container would begin leaking after 300 years and that all containers would leak after 1000 years. What this means, said Dr. Brewer, is that the geology and hydrology at the site must contain the contamination. Dr. Brewer said the Act discussed a water resource that could be used "without treatment".

He said that in Hanford's case, the regulations don't help much in dealing with groundwater development which is almost a certainty in the Hanford area. He said water not treatable now could be treatable 300 years from now, the principle of "mining" groundwater--which is depleting the resource as you go along--vs. a steady state, has a profound impact hydrology.

Dr. Brewer said there were only a few of these flood basalts in the entire world, as found in the Columbia Basin. He said the siting regulations are not always well adapted to the Columbia Basin.

Dr. Brewer said that the USGS is involved in a study called RASA--Regional Aquifer Systems Analysis--part of a national program to identify and characterize major aquifers in the whole country. He said RASA uses a simple five element model--sediments, sediment layers between them (in the basalt) and basalt below the Grand Ronde basalt. (He noted that the repository location is in the Grande Ronde.)

Dr. Brewer said that the RASA study said all future groundwater development for irrigated agriculture will come from the basalt. He said the survey inventoried present uses of resources of 45 million acres of basalt geology and about 2 million acres are under surface water irrigation. About .5 million acres are irrigated from deep irrigation wells which are in the basalts. He said it is possible the amount of withdrawal could increase dramatically and that the Survey said that another 3 million acres are potentially irrigable today. He said this figure could go up dramatically in 300 years, having a major impact on hydrology at the Hanford site.

Using slides, Dr. Brewer pointed out the areas of the USGS study. He said that the USGS views the hydrology differently than the USDOE and its contractors do in several respects, but there also are areas of agreement. The survey claims regional groundwater studies are needed. The USDOE activity (with direction by the NRC) is done very close to the repository site, at least most of the activity is located on-site. Dr. Brewer said an important point to discover is whether the aquifers are confined or if they freely move around the basin. The USGS says there is continuous movement of water and that the water always ends up in the Columbia River.

Dr. Brewer said that the sediments between the layers of basalt are the confining units, rather than the flows themselves. The USGS takes the same view that Bill Lingley was discussing, that while the basalt is not highly porous, it is permeable. The state Department of Ecology says that "the basalt is the aquifer", according to Dr. Brewer.

He said that the USGS survey indicated there were faults all throughout the basin, and that these faults can create pathways for groundwater movement. Dr. Brewer said he suggested there are major fault zones on four sides of the repository location. He said that the USDOE and its contractors said there are some "bedrock structural discontinuities" located there--which is another way of saying "fault". He said it would make more sense to spend $10 million now to confirm this, rather than spending $1 billion to site-characterize the location. He said there was a great deal of movement on the interior flows along fractures.

Dr. Brewer discussed the possible impacts of major withdrawals of water from the Hanford site. He said that some groundwater has come to the surface in the area. He said irrigating farmers put about 42" of water a year in their fields, which could be overkill. He said such irrigation would induce water rising from the deep aquifers. This phenomenon may radically alter the data already collected regarding groundwater travel times.

The Office of Nuclear Waste Management is proposing a study in great detail in the Pasco Basin--it is the WSU well-logging contract that has been before the Board for three years now, said Dr. Brewer, but still has not been implemented. He said he hoped this would tie in the information between the close-in and regional systeMs. The work the Office is proposing will go through one full irrigation cycle.

In summary, Dr. Brewer said that the Act is not very helpful in this special case. He said we must imagine Hanford in the future with good soil, a long-growing season, and the availability of water. Full development of that resource, however, would affect the groundwater movement and deep aquifers, according to Dr. Brewer. Probably this would impact the repository horizon. He thinks technologies are going to require us to get into many aspects of agriculture. He said that the Nuclear Waste Board will take the lead on a regional study of the wells. Dr. Brewer closed his presentation here.

Mr. Bishop opened the meeting for questions. Board member, Nancy Kirner, from the Department of Social and Health Services, mentioned that there is present concern about groundwater "mining" and she thought that legislation has been passed in this state to prevent that. She was concerned that there was a minimum amount of recharge of the water unlying the basalts.

Dr. Brewer said he wasn't aware of the legislation, but that department policies do prevent this. Ms. Kirner asked if we were likely to change our viewpoint on groundwater mining. Dr. Brewer said he hoped not, but it depended on legislative intent and economic interests.

Ms. Kirner said she recognized there was a disconnect between present and future resource management, but there is a concern we not draw down these resources that Dr. Brewer said we vitally need to feed the world's hungry.

Mr. Phil Johnson, Board designee from the Department of Ecology, said there are problems where we could deplete the groundwater or water tables would move to the surface. He said this often occurs in agricultural areas and causes nitrate pollution of drinking water.

Mr. Sam Reed asked what the losses were in irrigation to evaporation. Dr. Brewer responded that the way it is done here causes nearly 50% loss. He said that drip irrigation as used in Israel is much more efficient. Mr. Reed wondered if there was incentive if the cost of water was more expensive after a certain amount was used to help encourage conservation. Dr. Brewer asked how many irrigation districts we had in this state--it was unclear--but someone estimated at least 25 were in the Yakima Basin. Dr. Brewer responded by saying everyone is an entity in himself, and Mr. Roe said he did not know of any water purveyor doing what was suggested. Phil Johnson said that we are a Western Water Law state and if we don't use our water we lose it, which is a disincentive to conservation.

Mr. Reed said he understood that water rights were in excess of 100% at this time on the Columbia, at least in certain locations. Mr. Johnson said that he believed it was over allocated. Mr. Reed asked if someone knew what the percentage of over allocation was. Mr. Johnson said he couldn't answer that and perhaps Mr. Roe

could, but that in certain areas water rights are not adjudicated, so it is not determined who has what rights to how much water.

Ms. Valoria Loveland, Council member, said that drip irrigation was a large and new way of irrigating the Columbia River Basin, and that it is the largest such irrigation project anywhere in the continental U.S. Farmers are charged by the amount of water that is used, and are charged for excess. The average acreage for a family farm in the Tri-Cities area is about 300 acres, said Ms. Loveland. She said they pay about $10,000 to $15,000 a year just for the use of water. She guarantees the Board and Council that conservation is very important to the farm community, as well as all new technology associated with water conservation. Research through Washington State University, she said, has been very helpful in new irrigation techniques.

Ms. Loveland said that they don't have the exploration problems anymore that were discussed earlier, although they do have some nitrate probleMs. She said the Columbia Basin had learned a lot from California and their losses.

Mr. Lingley said that one thing the Shell wells showed was that potable water was available to great depths, such as to 16,000 feet.

Mr. Ray Issacson asked Dr. Brewer about his comment that basalts were the "aquifer" when in the sediment areas not even a teacupful of water was able to be drawn, and yet in other areas of basalts by Frenchman Springs water was abundant. Dr. Brewer said he thought it was a mistake to typify basalt over a large area by only using measurements from a specific area. The discussion between Mr. Issacson and Dr. Brewer continued along technical lines regarding basalt types and data that is needed. Dr. Brewer said we needed to look at the system as a whole. Mr. Issacson said he also was concerned about lack of recharge and problems related to groundwater mining. Dr. Brewer acknowledged it was a complex problem and that more data is needed. Dr. Brewer said that a fault can sometimes stop the flow of water.

Mr. Roe said he wanted to respond to a question Mr. Reed had asked earlier. He said two surface water systems--the Columbia and Yakima River systems--touch the Hanford Reservation. He said that the Yakima system is fully and over-appropriated. The Columbia River system is fully appropriated and there is a concern about the water rights for the need for water to operate repository projects.

Mr. Lingley said that a primary problem involving well drilling is a loss of circulation that occurs continuously in wells at depths of 7000 feet and less, and also below that depth.

Mr. Issacson commented about irrigation and that the soils in the Columbia Basin are primarily volcanic and have a high pH and a lot of alkali associated with the soil. Without good drainage, Mr. Issacson said, the soil would build up the alkali. He said soils could be destroyed if they are not flushed periodically, and this takes a large amount of water. He said that while the drip system is a good one, farmers must also rely on flushing to get rid of the alkali probleMs. Mr. Bishop said with that he wanted to bring the discussion this afternoon to a close, and expressed his appreciation to Mr. Lingley, Mr. Canard and Mr. Bloomquist, and also to Dr. Bill Brewer. Mr. Bishop said he had a commitment to meet with the Advisory Council this evening and wanted to close the meeting soon.

He presented a proposed resolution that the Advisory Council could consider that evening before the Board considered it tomorrow (Friday, February 20). The Chairman, Mr. Bishop, adjourned the meeting until 9 a.m. tomorrow morning.

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

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MEMORANDUM

February 10, 1986

TO: Nuclear Waste Board and Council

FROM: Bill Brewer

SUBJECT: Natural Resources Disqualifiers at a Repository Site; Background for Briefing on February 19

The Nuclear Waste Policy Act and the Siting Guidelines provide for disqualification of a repository site if "natural resources" are present such that in some future centuries their development would risk losing the geologic integrity of the surrounding rock. At Hanford there are three potential resources which could lead to this condition:

Petroleum: While there is no commercial production of oil or natural gas from the Columbia Basin, there is considerable exploration activity there even at a time when the industry is depressed. The Hanford Reservation is surrounded by leases and several deep exploratory wells have been drilled, with shows of natural gas. About ten miles south of the RRL a small field produced gas from the basalts until 1941. Today's exploration target is deep gas from sediments underlying the basalt formation. Exploration holes drilled for information at the repository site have shown natural gas (methane) in the groundwater. Bill Lingley and Curtis Canard will discuss the geologic and economic potential in the Basin and near the repository site.

Geothermal Energy: The state and the Geological Survey have mapped several areas of anomalous heat flow in the Columbia Basin which may be exploitable in the future for low-temperature applications such as heating and warm-water irrigation. Such applications will become increasingly attractive as time goes on and both the supply and the environmental consequences of fossil fuels require utilization of all appropriate energy sources. Gordon Bloomquist will discuss the known and potential resources of the area surrounding the Tri-Cities and Hanford.

Deep Groundwater Development for Agriculture: Surface water resources of the Columbia Basin are already, in principle, fully committed to often competing uses such as hydroelectric energy generation, fisheries protection and irrigation. It is inevitable that aquifers deep within the basalt formation will be exploited to bring additional lands under agricultural development; the Basin uniquely has both undeveloped lands and favorable climate available for expanded food production in the next century and beyond. Wells near Hanford are already producing from depths around 2,000 ft., only 1,000 ft. above the repository horizon. When the Hanford Reservation is finally abandoned agricultural exploitation of this resource will have profound hydrologic consequences for rates and directions of groundwater movement from the repository toward the environment. Bill Brewer will present perspectives on deep groundwater development in the Pasco Basin and discuss recent appraisals by the U.S. Geological Survey.

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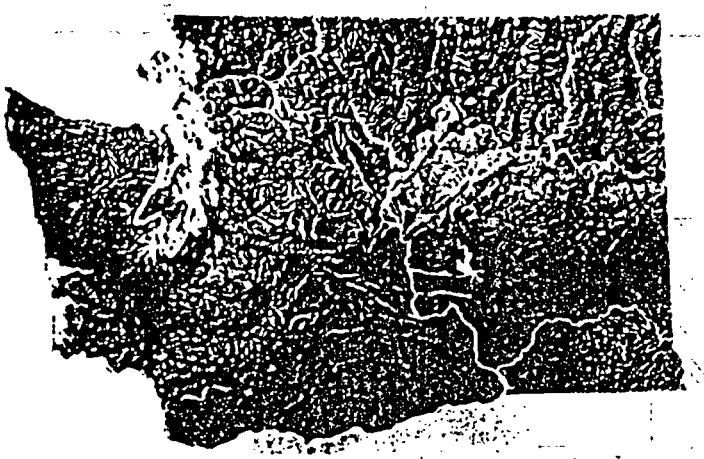

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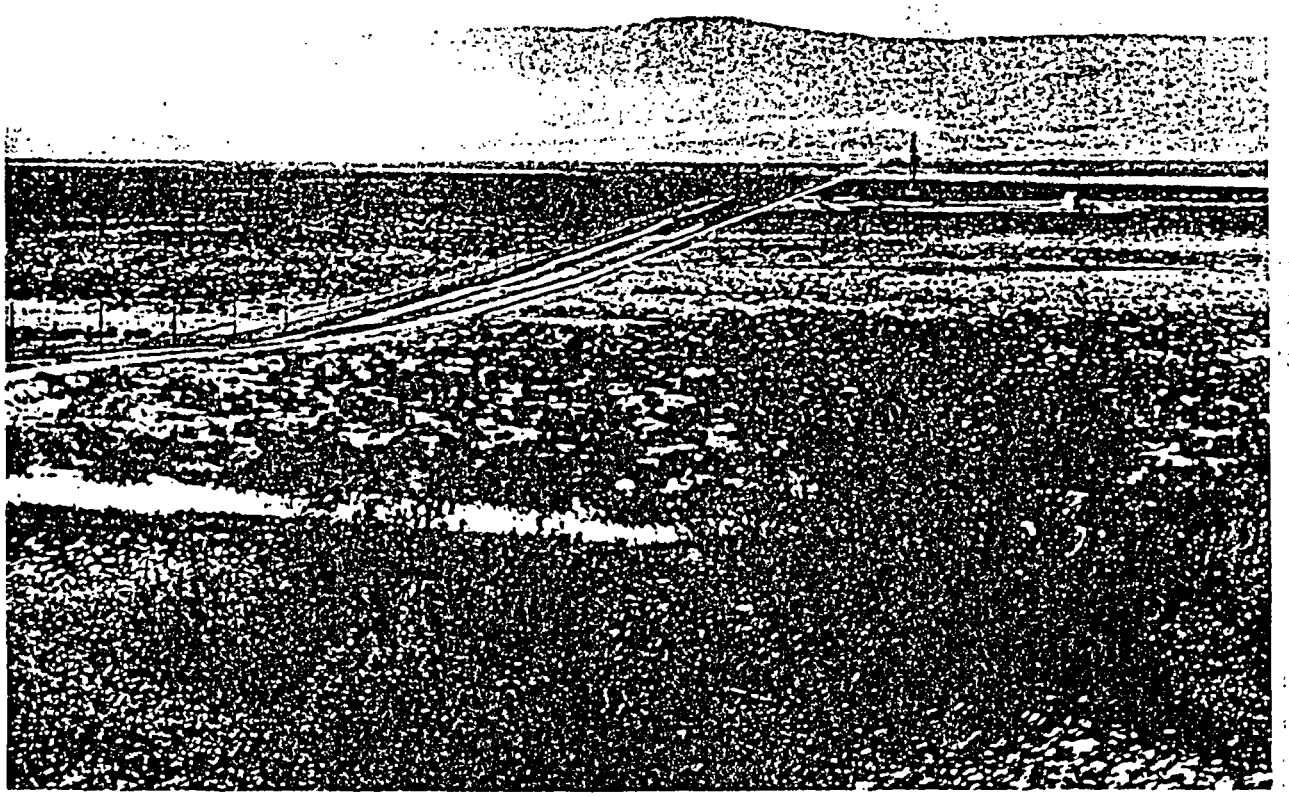

The Basalt Waste Isolation Project site, Hanford Reservation, Washington. The drill is situated at the proposed shaft site on the Cold Creek syncline. The hills in the background are the Rattlesnake Mountains, wells on which produced 1.3 billion cubic feet of natural gas between 1929 and 1941. See related articles in this newsletter. (Photograph courtesy of the U.S. Department of Energy)

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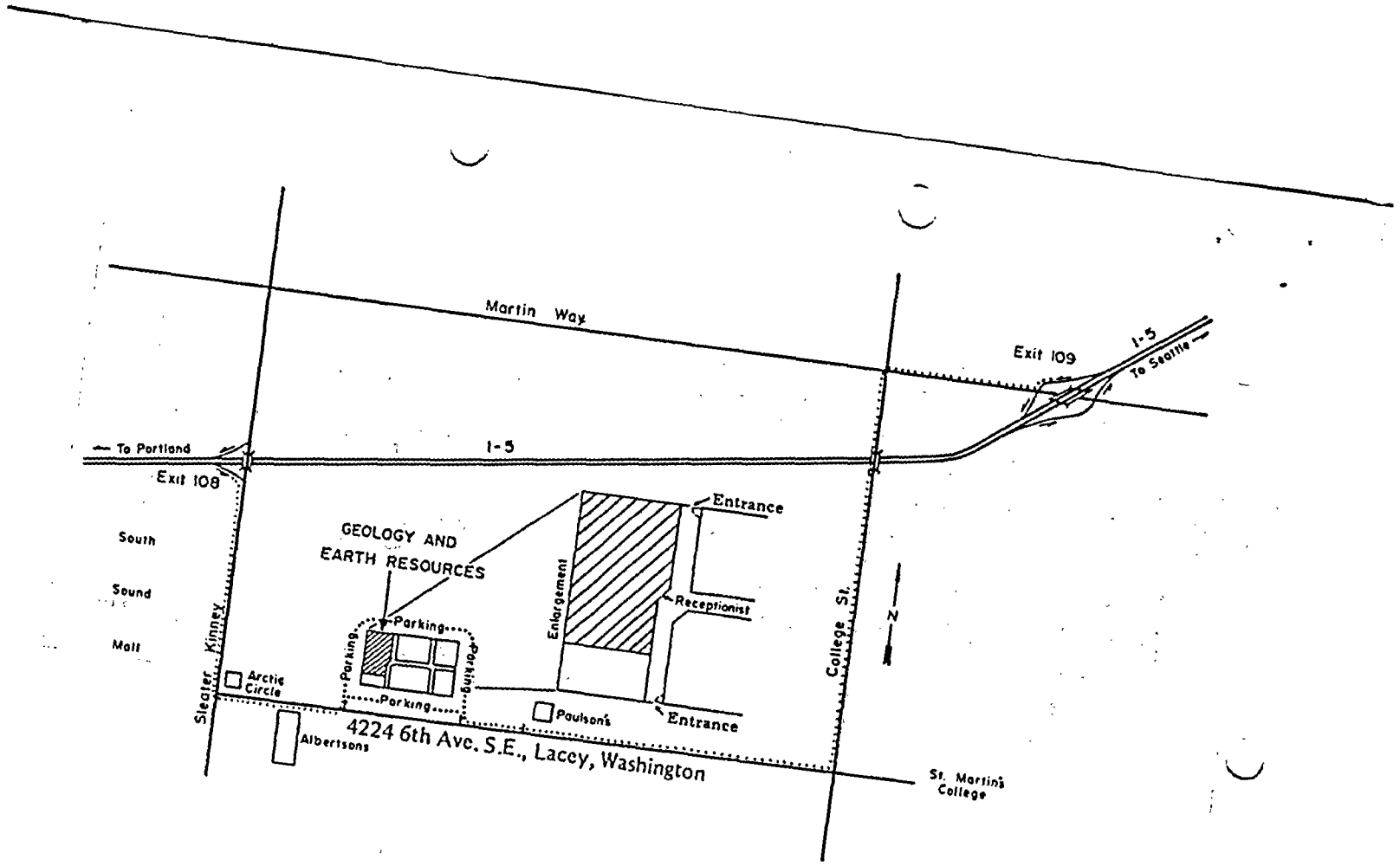

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The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request.

The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

ISSUES RELATING TO PETROLEUM DRILLING NEAR THE PROPOSED HIGH-LEVEL NUCLEAR WASTE REPOSITORY AT HANFORD

by

William S. Lingley, Jr.
and Timothy J. Walsh

In February 1986, the Office of Nuclear Waste Management of the Washington State Department of Ecology requested that the Division of Geology and Earth Resources assist in a study of future petroleum activities in the vicinity of the proposed high-level nuclear waste repository at Hanford. The objective of this study is to determine the probability that the repository could be accidentally breached as the result of drilling for oil or gas. If significant probability for such an accident exists, then Hanford will not meet the U.S. minimum qualifying conditions for nuclear waste repository siting (10 CFR 960-4-8-1a). Our preliminary findings suggest that the probability of such an accident is low. These findings were presented to the Northwest Petroleum Association during their 1986 annual meeting (Lingley and Walsh, 1986). This article discusses the issues and describes some ongoing studies designed to reach a more conclusive decision on the breaching issue.

The U.S. Nuclear Regulatory Commission is concerned that, in the distant future, accidental breaching may occur at the repository despite prohibition of access to the Hanford Reservation and despite the elaborate hazard warning system planned for the repository. The minimum effective life span of the repository must exceed the 10,000 years necessary for the waste to decay to minimum acceptable radiation levels (Brewer and Lasmanis, 1986). Consequently, it is probable that the repository will outlast present political institutions, and it might also outlast written record of the presence and dangers of the radioactive nuclides stored in the repository chambers.

Accidental breaching could result from drilling directly into the repository or from drilling nearby and, as a result, exposing rocks contiguous with the repository to formation fluids or drilling fluids capable of leaching fracture-filling minerals in the chamber walls. The apparent probability of either type of breach is low, given that the Columbia Basin, in which Hanford is located, is covered with a thick section of Columbia River basalt which is relatively unprospective for oil and gas and given that petroleum is not presently produced in Washington State. ("Prospective" is used as in the industry idiom to indicate favorable possibilities for oil or gas accumulation(s) at a given location. "Petroleum" is used here in the legal sense and includes oil, gas, and gas condensate).

However, Shell Western Exploration and Production, Inc., and others have undertaken a relatively aggressive exploration program in the basin. During 1986 alone, the Division of Geology and Earth Resources has received permit applications for acquisition of more than 250 line miles of seismic data and for drilling a 15,000-foot wildcat well, the Boylston Mountains Unit No. 2-1. This well will be located 40 miles northwest of the proposed waste repository site (Fig. 1). This exploration program, undertaken during a severe recession for the petroleum industry, suggests that this part of the Columbia Basin is prospective.

A central question is whether the proposed repository site is sufficiently prospective to attract drillers to those areas having hydrologic continuity with the repository. In order to answer this question, we have commenced studies of the petroleum potential of the repository proper and of the northwestern Columbia Basin. Previous work by Leaming and Davis (1983) dealt only with the petroleum potential of the basalt, and work by Campbell and Banning (1985) concentrated on regional stratigraphy.

Petroleum Potential at the Proposed Repository Site

The first step in assessing the probability of accidental penetration of the repository is to find obvious prospects for petroleum accumulations at or near the proposed repository site. Prospects are usually delineated by mapping anticlines or faulted anticlines having potential to trap oil and/or gas migrating out

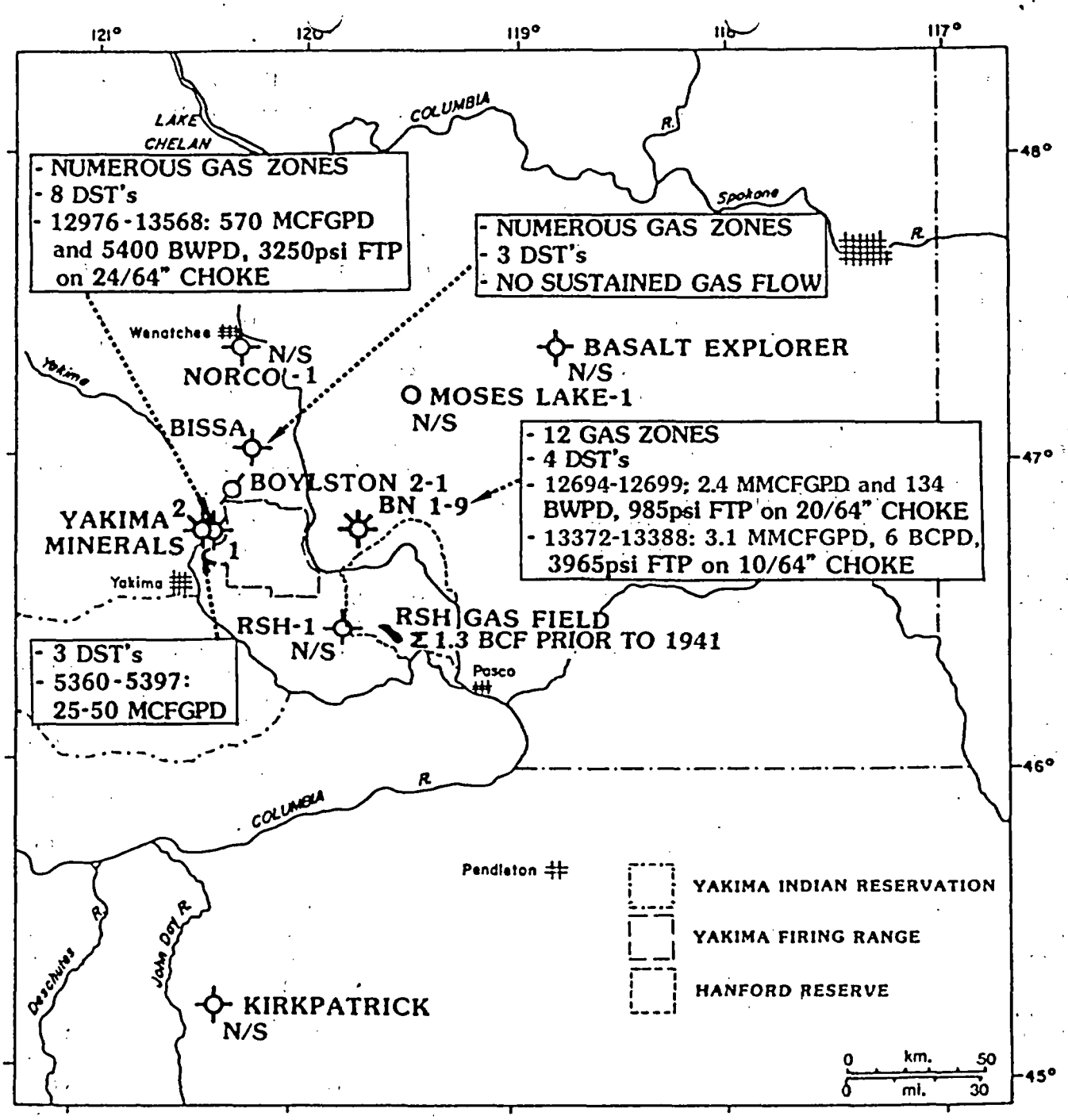

Figure 1. Index map showing locations of important northern Columbia Basin wildcat wells with data on relevant petroleum shows and drillstem tests (DST's). BWPD, barrels of water per day; BCPD, barrels of condensate per day; FTP, flowing tube pressure; N/S, no shows; BCF, billion cubic feet; MCFGPD, thousand cubic feet of gas per day. All depths in feet referenced to the kelly bushing.

of petroleum source rocks. In some parts of the Columbia Basin, structural geometry at depth can be deduced by extrapolation of structure as mapped at the surface downward to the most prospective horizons. These horizons comprise Paleogene sandstones, which generally lie at depths of 5,000 to 14,000 feet. However, it is likely that some Columbia Basin anticlines fold only Paleogene strata and have no manifestation in the basalt or at the surface. There is no definitive, yet inexpensive means of mapping these deeper structures in the Columbia Basin with present technology. Relatively inexpensive prospecting techniques, including interpretation of gravity, magnetic, and electromag-

netic data, have failed to yield prospect-scale information owing to limited resolution.

In order to locate possible prospects, we recommend that mapping of surface structure be augmented with state-of-the-art, regional reflection seismograph traverses across the site. These new traverses should be included in the ongoing petroleum assessment that is part of the Hanford site characterization study. The traverses should be planned so as to avoid interference from known faults and so as to decrease accoustical noise by having the line laid out on alluvium rather than on basalt. We believe that a meaningful assessment cannot be accomplished without acquisition of these seismic data.

An alternative to seismic traverses being considered by the U.S. Department of Energy (USDOE) and the Nuclear Regulatory Commission is drilling a well at the repository site through the basalt and into the more prospective Paleogene rocks to a total depth of approximately 15,000 feet. The estimated cost of this drilling program exceeds $10 million. We oppose this proposal because the results of such drilling may be equivocal, providing information for only one point, and therefore may not justify the high cost to utility ratepayers. Shell's experience gained by drilling and testing three sub-commercial discoveries in the vicinity of Hanford indicates that numerous gas zones are likely to be penetrated if a well is drilled at Hanford. In order to determine the magnitude of gas reserves in these zones, many will have to be stimulated and tested at additional expense. The probable result of this testing program will be that none of these zones is commercial under present-day economic constraints. However, it is not difficult to envision a wellhead gas price many times greater than the present $1.50 per thousand cubic feet, considering the non-renewable nature of petroleum resources and the likely demand for natural gas to be used as a petrochemical feedstock in the future. It is likely that a future wildcatter would find a greatly increased gas price to be a strong incentive for re-entering a well already drilled and cased through the basalt. Hundreds of wells originally abandoned as dry holes were re-entered for just this reason during the 1970s. If public records should cease to exist, the plugged well could be located because of the magnetic signature of the casing. Under this unpleasant but possible scenario, the well drilled for the very purpose of deciding if it is necessary to keep future explorers out of the repository area would have precisely the opposite effect (unless a carefully reasoned plugging program for this 15,000-foot test and for the numerous shallower wells already drilled by USDOE is developed).

Regional Petroleum Potential of the Columbia Basin

It is reasonable to assume that some form of direct petroleum detection technology may be developed during the life span of the repository and that use of this technology may result in successful exploration in areas such as Hanford where no obvious manifestations of petroleum potential exist today. Direct detection or other new exploration technology could be applied to the greatest advantage in unexplored basins that have significant theoretical but untested potential to produce hydrocarbons. Historically, petroleum has been discovered by drilling at locations proven by mapping to be analogous to existing oil or gas fields. Some small accumulations, trapped by structure, hydrodynamics, or stratigraphic pinchouts too subtle to map using existing technology, have been discovered accidentally by drilling in thoroughly explored basins. However, closely spaced drilling in almost all onshore basins in the United States diminishes the probability of large new oil or gas discoveries from anticlinal or subtler types of traps because the remaining unexplored area is insufficient for typical large petroleum fields. For example, the Powder River Basin, a productive basin in northeastern Wyoming roughly equal in size to the Columbia Basin, has had more than 27,000 wells drilled for oil and gas. On the other hand, the Columbia Basin, where only nine wells have been drilled to date, is the least explored, large onshore basin in the United States. Consequently, it is likely to have more intensive exploration in the future if reasonable hope for a commercial discovery exists.

The basic ingredients of a petroleum-generative province are present in the Columbia Basin. For example, sedimentary rocks in excess of 10,000 feet thick were penetrated in the Yakima Minerals 1-29 well (Figs. 1 and 2). Gas shows were logged in

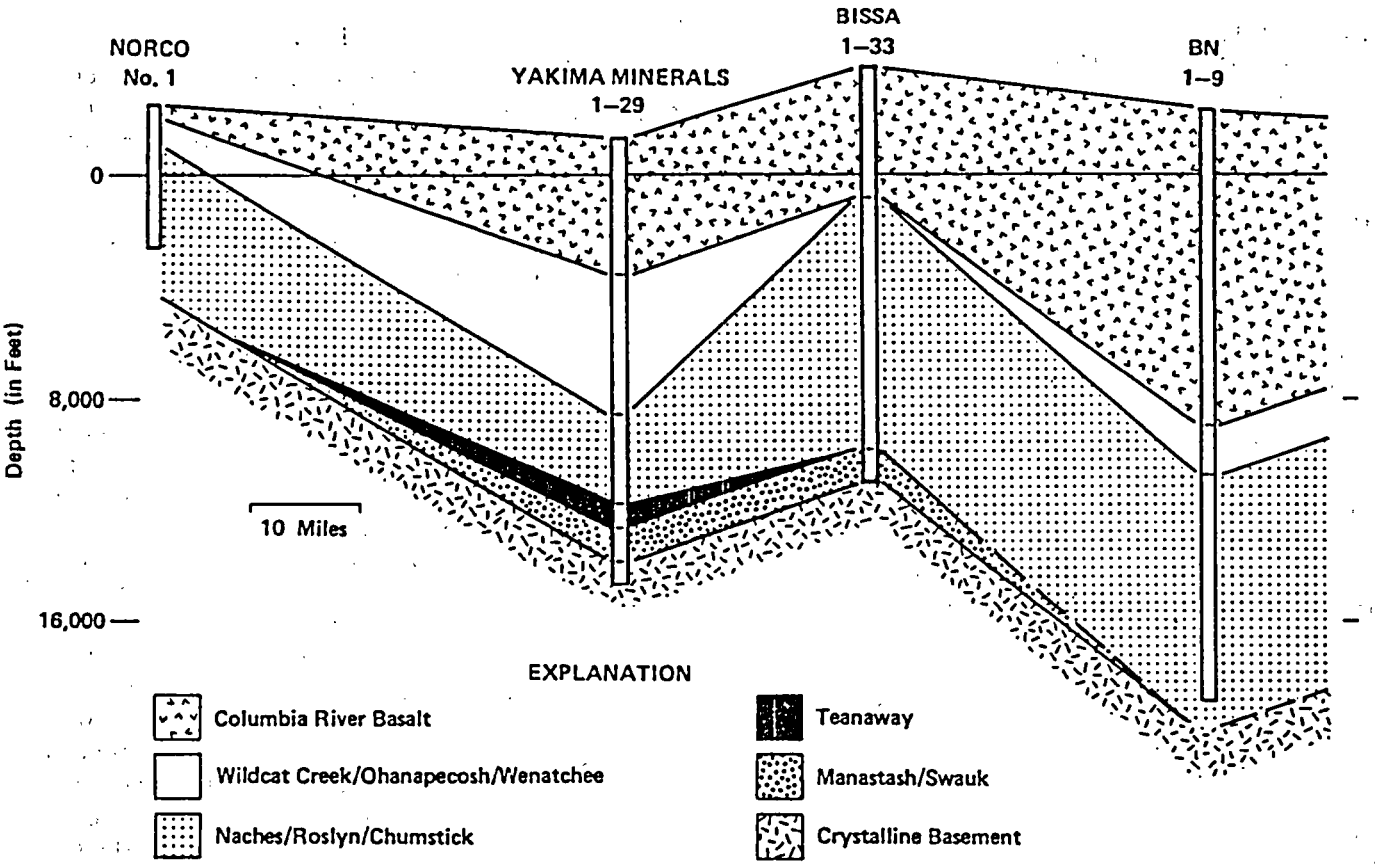

Figure 2. Correlation diagram for selected Columbia Basin wells. Interpretation is from Campbell and Banning, 1985; N. E. Campbell, personal communication, 1986; and J. E. Evans, University of Washington, written communication, 1985.

all wildcat wells drilled into the sedimentary section and in numerous water wells drilled into the Columbia River basalt. We calculate moderately high geothermal gradients (+/- 40°C/kilometer), which are optimally conducive to generation and preservation of petroleum. The reflectance of vitrinite, a coal maceral, is considered to be a maximum-reading paleo-thermometer. We have measured vitrinite reflectance values between 0.5 and 1.0 which also demonstrate that much of the sedimentary section is thermally mature for petroleum generation (Fig. 3, Table 1). Large, doubly-plunging or faulted anticlines are common (Fig. 4) and provide abundant traps. Furthermore, 1.3 billion cubic feet of natural gas were produced from the Rattlesnake Hills gas field prior to its abandonment in 1941 (McFarland, 1983). This field, located in a subsidiary fold on the north flank of the Rattlesnake Hills anticline, lies within the Hanford Reservation a few miles from the proposed repository (Fig. 1).

The obvious questions many laypersons ask when presented with this information are, "Why aren't hydrocarbons being produced at present, and why haven't more exploratory wells been drilled if the Columbia Basin is such a good place to search for petroleum?" Three obstacles have impeded successful exploration in the Columbia Basin: (1) the difficulty in drilling through the basalt (2) the difficulty of obtaining seismic data, and (3) the gas-generative nature of the source rocks.

Basalt is difficult to drill because of its hardness and because of the problems of maintaining drilling-mud circulation while penetrating numerous, highly permeable fracture zones that characterize these rocks. The Shell BN 1-9 well located directly north of the repository and the Standard Oil of California Rattlesnake Hills No. 1 well located within the Hanford Reservation both drilled through more than 10,000 feet of basalt (Figs. 1 and 2); these were unusually expensive projects, and neither penetrated commercial gas zones.

It is particularly difficult to acquire high-quality seismic data in basalt because of

low signal-to-noise ratios and because of poor coupling between the seismic signal receivers and basalt outcrops. Complex faulting, which is common in the vicinity of the proposed repository, also diminishes the quality of seismic records and hinders interpretation. However, a future explorationist may regard this complexity as an advantage because complex faulting generally results in numerous potential petroleum traps.

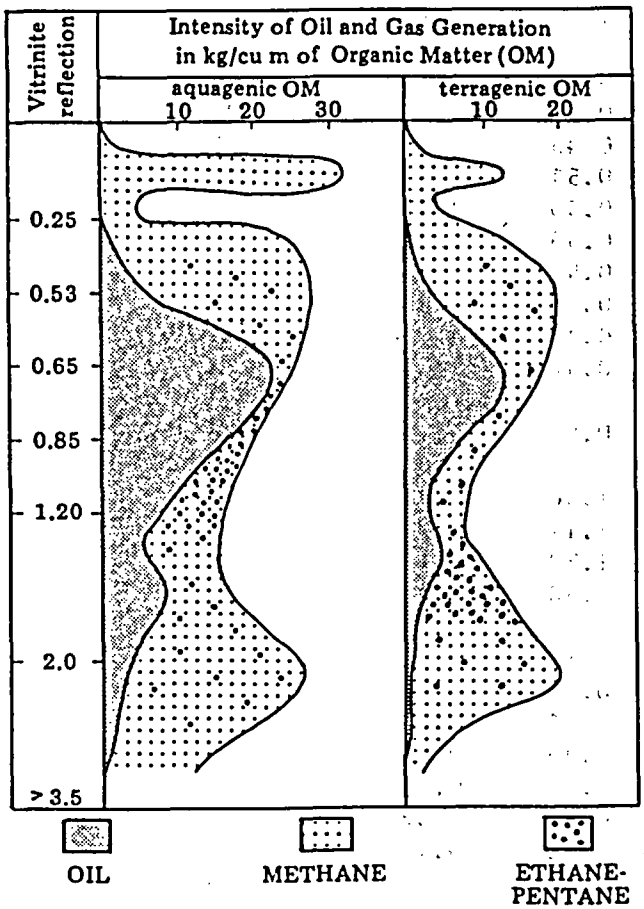

Figure 3. Suggested correlation between vitrinite reflectance and hydrocarbon generative potential (from Kontorovich, 1984.)

No public data, except those herein and in Lingley and Walsh (1986), are available to characterize the quality of the petroleum source-rocks. The USDOE and the Washington State Office of Nuclear Waste Management plan to evaluate the source potential and maturation levels of selected intervals in the Shell wells and in the Norco well (Fig. 1) during the site characterization study.

Despite the paucity of data, petroleum shows logged to date give an indication of the general nature of the source potential of the northern part of the basin. These shows suggest that the source rocks in this part of the basin will probably generate natural gas only. Gas or gas-condensate shows have been recorded throughout the sedimentary section of the northwestern part of the basin, but no oil shows have been logged to date. Much of the sedimentary section in the basin lies within the oil-generative thermal window (Fig. 3), and therefore, we infer that if areally extensive oil-prone source rocks were present in the basin, oil shows should have been observed. Although we expect most future wildcats will penetrate some gas zones, the possibility for an oil discovery cannot be ruled out because few holes have been drilled through the basalt. On the other hand, gas source-rocks are evidently present in abundance in the basin. Gas shows are so ubiquitous that few 100 percent water-bearing reservoirs are present in the Paleogene section. Water-bearing zones are critical for normalizing the responses of sondes used to determine such petrophysical characteristics as porosity and water saturation (the percentage of water that partially fills most pore space below the water table). Nevertheless, natural gas is a less attractive product than oil because of traditionally soft markets and because of high transportation costs. Gas pipeline construction can cost $40 per linear foot, and gas gathering and compression generally cost in excess of a million dollars per field. Because only small markets exist nearby, gas would have to be transported large distances to users.

Even if these three technological problems related to exploring this basalt-covered basin are solved, there remains a question as to whether the potential petroleum reserves in the basin are sufficient to encourage further exploration. In order to answer this question, it is necessary to determine why tests drilled through the basalt into prospective rocks have been sub-commercial discoveries at best. The Yakima Minerals 1-29, located 45 miles west-northwest of the proposed repository, tested 500 thousand cubic feet of gas per day (MCFGPD), and the BN 1-9 tested 3,100 MCFGPD. These rates are commercial for typical wells, but not for wells in the Columbia Basin where the development wells

Table 1. Mean random vitrinite reflectance measurements on coals from selected wells in the Columbia Basin

Well name	Depth interval (feet)	R_o (mean)	Standard deviation	Number of Measurements
Shell BN 1-9	11280-11290	0.54	0.02	50
Grant County	11990-12000	0.63	0.03	50
965' FWL, 1869' FNL	15110-15120	1.13	0.09	50
sec. 9, T. 15 N., R. 25 E.	15160-15170	1.15	0.11	31
	15810-15820	1.32	0.12	50
Shell Bissa 1-29	4620- 4630	0.43	0.05	50
Kittitas County	5150- 5160	0.39	0.04	38
1318' FEL, 1928' FSL	5820- 5830	0.45	0.05	75
sec. 29, T. 18, R. 21 E.	6480- 6490	0.51	0.05	77
T.D. = 14,965 ft.	6890- 6900	0.50	0.05	75
	7600- 7610	0.53	0.06	75
	8560- 8570	0.57	0.06	100
	9210- 9220	0.53	0.06	79
	9590- 9600	0.47	0.08	41
	10070-10080	0.57	0.05	53
Shell Yakima Minerals 1-33	9840- 9850	0.86	0.11	76
Kittitas County	10070-10080	0.91	0.07	74
925.5' FNL, 1445.6' FWL	10370-10380	1.08	0.08	75
sec. 33, T. 15 N., R. 19 E.	10805-10810	1.11	0.09	61
T.D. = 16,199 ft.	11010-11020	1.20	0.13	75
	11860-11870	1.38	0.12	75
Norco No. 1	1751- 1760	0.39	0.03	54
Chelan County	1920- 1930	0.39	0.03	7
NW1/4 NW1/4 SW1/4 sec. 26,	2253- 2260	0.51	0.05	51
T. 22 N., R. 20 E.	2400- 2410	0.49	0.08	53
	2535- 2540	0.48	0.06	24
	2690- 2700	0.32	0.02	45
	2785- 2790	0.42	0.17	4
	2885- 2890	0.28	0.03	25
	3144- 3150	0.35	0.03	51
	3305- 3310	0.47	0.04	48
	3444- 3450	0.42	0.06	26
	3692- 3700	0.51	0.05	50
	3972- 3980	0.50	0.06	24
	4208- 4220	0.77	0.07	11
	4671- 4680	0.66	0.07	57
	4840- 4850	0.51	0.06	69

necessary to establish commercial production may cost $8 to 14 million each. Flow-test data indicate that the reservoir sandstones penetrated by the Yakima Minerals 1-29 and the BN 1-9 wells are not sufficiently extensive to sustain production. Furthermore, many of the sandstones are composed mostly of volcanogenic detritus. This detritus tends to break down to form clays or other minerals that reduce porosity and/or permeability within the reservoir. The alteration appears to be a function of depth of burial.

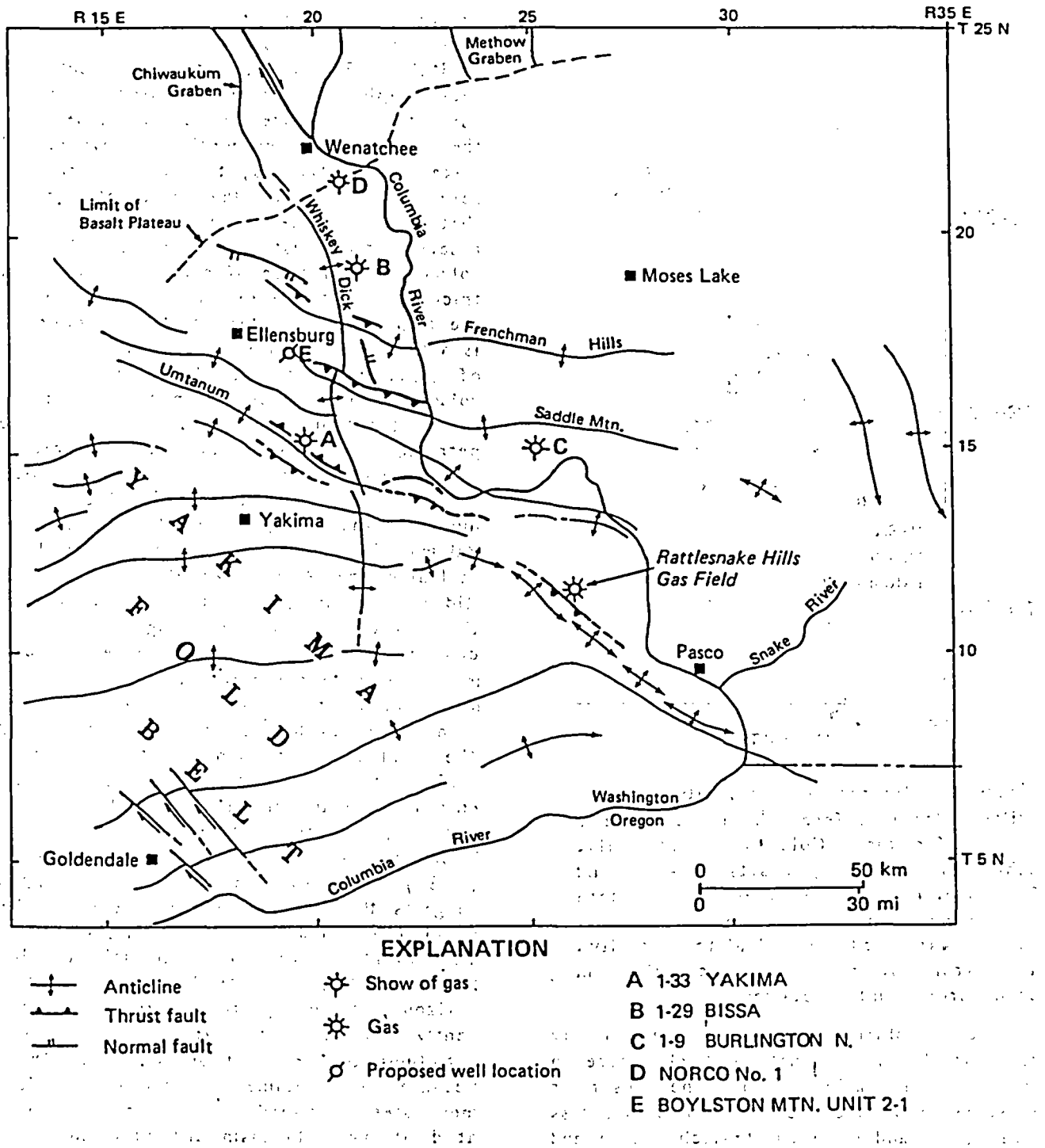

Figure 4. Structure map of the Yakima fold belt and adjacent basins to the north (from Montgomery, 1985).

We determined that mean sandstone porosity, expressed as a percentage of the bulk volume of the rock, is 18 percent at 6,000 feet drilled-depth. Mean sandstone porosity is reduced to only 8 percent at 14,000 feet, regardless of the age or composition of the sandstone present at this depth (Fig. 5). Generally, petroleum cannot flow at high rates through rocks having 8-percent porosity unless expensive and risky mechanical fracturing of the strata is performed to artificially increase permeability.

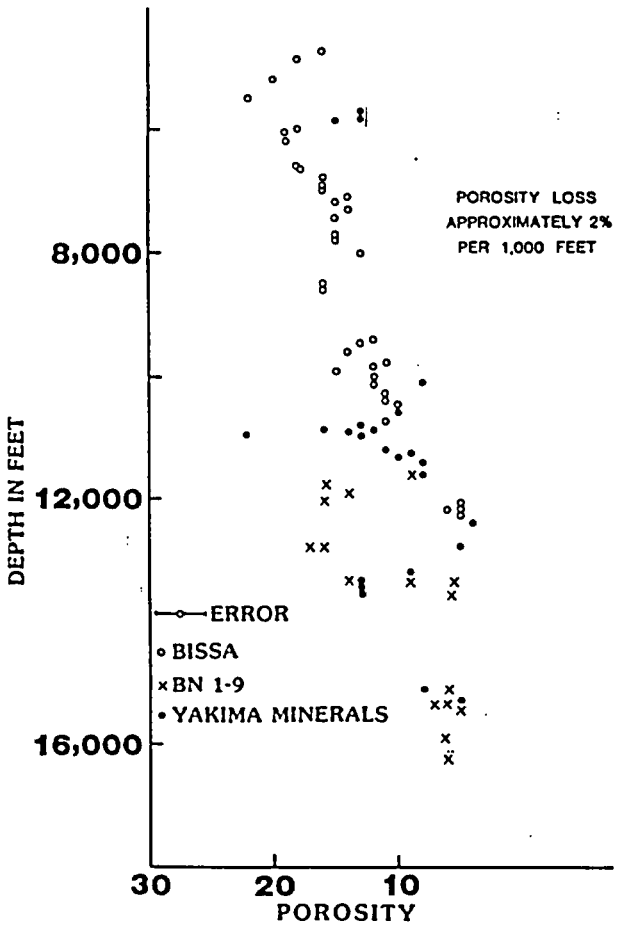

Figure 5. Interpreted porosity versus drilled depth referenced to the kelly bushing for three Columbia Basin wells. Schlumberger (1984) charts Por-14b and Por-15 were used to determine the bore hole environmental corrections and chart CP-1d was used to calculate porosity. The error bar shows the uncertainty in each porosity interpretation.

These problems relating to the porosity and permeability may not exist elsewhere in the Columbia Basin, where the reservoir sandstones may have been derived from a less volcanogenic and more quartz-rich source and where prospective Paleogene rocks lie at a shallower depth. One area having potential for better porosity is located in the east-central part of the basin, directly east of Hanford. Shell is presently concentrating their seismic acquisition program in this area.

If future explorationists wish to undertake further investigations in the basin, they may have to convince management that major reserves are present in order to justify expenditure of considerable amounts of risk capital. To simulate the arguments that these explorationists might invoke, we have estimated the range of possible reserves in the event of a commercial discovery. To make these estimates, the potential range of reservoir volumes and the amount of petroleum that can be squeezed into a unit volume of reservoir rock must be determined. Reservoir volume is a function of porosity of the rock, thickness of the reservoir, areal extent of the trap, and percentage of the reservoir that is actually filled with petroleum. The amount of petroleum that can be held in a unit volume of pore space within a reservoir rock is a function of pressure, temperature, petroleum composition, and water saturation.

Normally, the most significant variable is the size of the petroleum trap. The proposed nuclear waste repository lies within the Yakima fold belt where large anticlines, including the Rattlesnake Hills, the Yakima Ridge, and Umtanum anticlines, impinge on the Hanford Reservation (Fig. 4). These complex folds are mostly asymmetric, commonly verge to the north, range from 3 to 6 miles across strike, and are from 75 to more than 100 miles long as measured along trend. The surface expression of these folds is similar in size and morphology to folds that entrap the giant oil and gas fields of Iran, Rumania, western Alberta, and western Wyoming. Our analysis of mapping by Bentley (1980) and Swanson and others (1979) suggests that trap areas within the fold belt could range from 3,000 to 25,000 acres. The average area of potential anticlinal petroleum traps at the Paleogene sandstone horizons, as interpreted herein, is significantly less than the area of these same anticlines as mapped at the surface. This is because the anticlines are thought to plunge more steeply towards the center of the basin at depth owing to basinward thickening of the basalt. The thickness of the basalt cannot be determined with precision, but interpretation of well and geophysical data suggests that the basalt thickens toward a depocenter in the Pasco subbasin directly north of the repository. However, no data are available to indicate whether the Yakima fold belt anticlines maintain anticlinal morphology within the sedimentary rocks underlying the basalt at the repository.

We predict that fault traps are more likely than anticlinal traps at depth in the basin.

The average porosity of the Paleogene sandstones known to contain gas in the Columbia Basin ranges from less than 6 to approximately 18 percent (Fig. 5). Our work shows that the average thickness of sandstone reservoirs logged in the BN 1-9, Yakima Minerals 1-33, and Bissa 1-29 wells that have greater than 6 percent porosity is approximately 26 feet (Fig. 6). We calculate that the volume of typical Columbia Basin natural gas that can be contained in one cubic foot of pore space at the predicted reservoir pressure and temperature at 5,000 feet drilled-depth is approximately 150 standard cubic feet of gas. At 14,000 feet drilled-depth, approximately 350 standard cubic feet of gas can be contained in one cubic foot of pore space because gas is highly compressible.

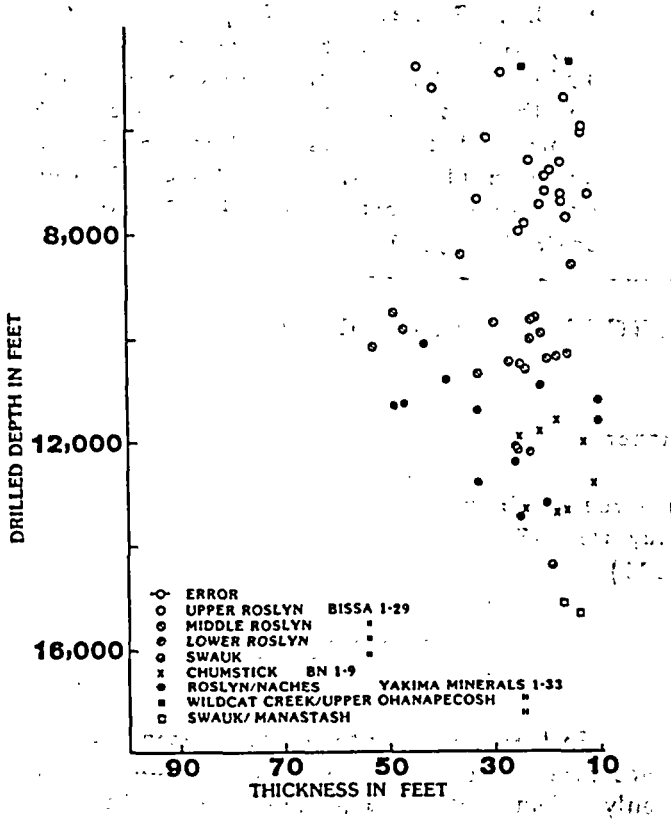

Figure 6. Thicknesses of sandstone having greater than six percent porosity versus drilled depth referenced to the kelly bushing for three Columbia Basin wells. Porosity was determined using the technique given in Figure 5. The thicknesses given represent only those sandstones having relatively uniform porosity; thick siltstone or claystone interbeds are considered to segregate a unit into two or more sandstones for the purposes of this figure. Error bar indicates the uncertainty for each thickness measurement.

These data and interpretations suggest to us that possible petroleum reserves in the vicinity of the proposed repository site range from 40 billion to 1 trillion cubic feet of gas initially in place per trap. The larger volume estimate is based on assumptions of good reservoir characteristics and three stacked pay zones; less conservative gas reserve estimates determined by using these same data will be much greater. Typical recovery currently achieved from gas reservoirs is 60 percent of the gas initially in place in the trap. A giant gas field, that is, a field with sufficient reserves to have major favorable economic impact, is defined as one in which 1 trillion cubic feet of gas can be produced. The potential for reserves of this magnitude is the reason why Shell and others persist with difficult and expensive exploration in the Columbia Basin. It is also the reason why the potential for accidental breaching of a high-level nuclear waste repository, if sited at Hanford, requires thorough investigation before it will be known whether this site will meet the minimum Federal guidelines. More detailed study of the petroleum geology of the greater Columbia Basin is now in progress.

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INDOOR RADON AND ITS SOURCES IN THE GROUND

by
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Introduction

Radon is a radioactive element that is produced by the radioactive decay of radium, which itself is derived indirectly from uranium. When radon disintegrates, it produces radioactive decay products that are now recognized as an important cause of lung cancer. Uranium, radium, and radon are naturally present in very small concentrations in nearly all soils and rocks. There are typically only a few radon atoms among the 10,000,000,000,000,000 molecules of air in a pore space in the soil. The radon atoms do not combine with other elements but can diffuse or can be carried along with air from the soil into a house through openings such as cracks, joints, sumps, and utility penetrations in basement foundations and walls or through floor openings from crawl spaces above the soil.

What causes soil air to move into a house?

Soil air moves into a house when the air pressure inside the house is lower--even if only a hundredth of a percent lower--than the atmospheric (barometric) pressure outdoors. Wind blowing by the house can reduce the air pressure in the house, depending upon the positions of open windows and other openings. If the air in the house is warmer than the outdoor air, it is more buoyant, can leak out at the upper levels of the house, and "draw" cooler air in from below, just as a fireplace does. In effect, lowered air pressure makes the house a large vacuum cleaner, sucking some air from the soil and some air from the outdoors near ground level.

If an ice or clay apron, or concrete deck outside offers resistance to the movement of air from the soil to the atmosphere,