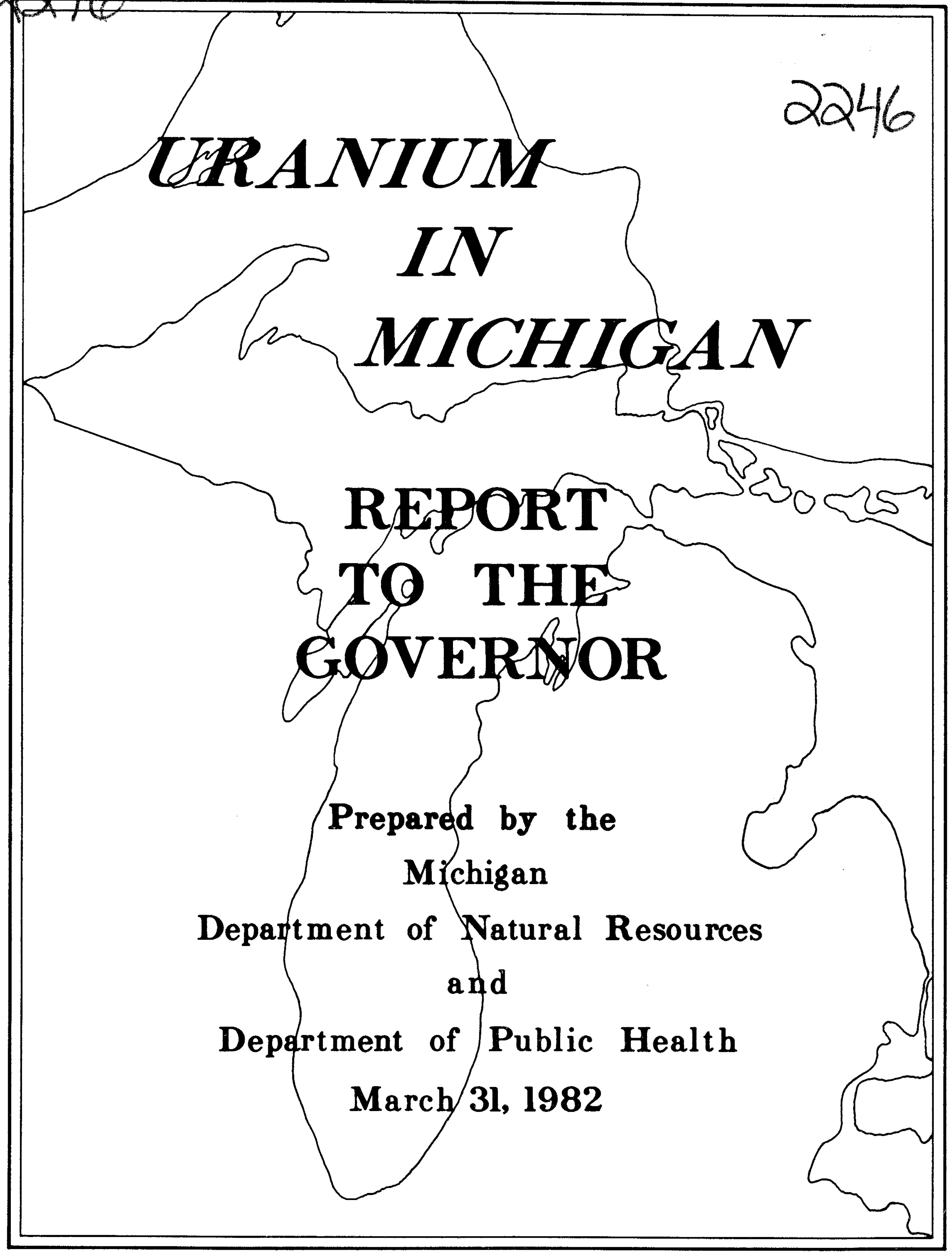

URANIUM IN MICHIGAN

REPORT TO THE GOVERNOR

Prepared by the

Michigan

Department of Natural Resources

and

Department of Public Health

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SUMMARY

This report has been prepared at the request of the Governor. It's preparation was stimulated by mining industry interest in leasing approximately 400,000 acres of state-owned lands in the Upper Peninsula for base metal exploration and potential mining development. Uranium was one of the metals of interest. Uranium, with its property of radioactivity, has been a socially controversial element or, more accurately, the use of uranium in the nuclear power industry and in the military have been controversial. Thus, when the DNR held public hearings in July of 1980 to receive comments on a proposed metallic lease, two issues were identified. One dealt with the adequacy of the proposed lease and the second with the propriety of leasing state land for uranium exploration and development.

Citizens were concerned with the environmental and health hazards associated with uranium exploration, mining and milling. Uranium mining had never occurred in Michigan, but they had read or heard of the environmental and public health problems with existing uranium projects in Canada and the western United States. They were worried about the potential development of uranium mining in the Upper Peninsula. Specifically, they questioned the adequacy of existing public health and environmental statutes with respect to uranium exploration and mining and the ability of federal and state agencies to adequately monitor specific mining activities, obtain compliance with permit conditions and pursue enforcement and corrective action, when necessary, in a timely manner.

These concerns were expressed to the Governor and in August of 1980 the Governor directed the departments of Natural Resources and Public Health to study the potential environmental and human health risks associated with uranium exploration and mining as well as review the existing regulatory framework under which uranium mining would be carried out in Michigan. A hold was also placed on the leasing of any state land for uranium exploration and development pending the completion of the report.

In addition to public health and environment issues associated with uranium exploration and development, there were positions of complete opposition to uranium exploration, mining and milling in the Upper Peninsula on moral, philosophical and religious grounds. It was submitted that the development of uranium mining would aid in the proliferation of nuclear weapons and in the development of nuclear power. These were opined as immoral activities and the state, by entering into leases for uranium, would be acting immorally. This report does not address the social and ethical question to the uranium controversy.

This report does address two issues. 1) A review of the potential environmental and human health impacts relating to uranium exploration, mining and milling. 2) A review of the existing federal and state law in place to regulate uranium exploration, mining and milling.

It is necessary to point out that this report is prospective in nature. Uranium exploration activities currently underway in Michigan are at an early stage of mineral exploration. There are no uranium mines in the state. No state-owned lands are under lease. We view this report as a guide to aid in framing the issues and identifying the existing regulatory controls on uranium mining.

MAJOR OBSERVATIONS

A. Health Effects

1. The health effects of ionizing radiation are divided into acute radiation effects which occur at whole body exposure of 50 rems or more and subacute effects which occur at less than 50 rems. There are also delayed somatic effects which are not expressed for several months or years after the initial exposure and are observed as leukemogenic, carcinogenic or mulagenic changes.

2. Acute radiation effects have been documented from studies of laboratory animals and epidemilogical studies of humans. Human exposure data has been obtained by studying the survivors of nuclear explosions and nuclear weapon testing as well as individuals receiving medical radiation therapy.

3. The health effects of humans exposed to low levels of ionizing radiation (less than 1 rem) is not as completely understood as the health effects of humans exposed to high levels (greater than 50 rems).

4. The health effects of ionizing radiation are known to be dose dependent, but at low levels of exposure (dose) there is scientific debate on the exact cause-effect (dose-response) relationship and at which point exposure has no further biological effect.

5. For purposes of setting radiation standards to protect the general public and occupational workers, international, national and state scientific advisory boards and regulatory agencies take a conservative approach and assume for the purposes of risk assessment there is no threshold limit for low levels of ionizing radiation and that fraction of individuals affected would be proportional to the dose down to zero.

6. Radiation standards are developed to cover occupational workers and the general public and the basic goal of the standards is to set the maximum permissible dose as the highest dose of ionizing radiation that is not expected to cause appreciable bodily injury to a person at any time during his or her lifetime.

7. Naturally occurring or background levels of ionizing radiation in the United Stats and in Michigan is approximately 100 mrems/year (0.10 rems).

8. The recommended average annual exposure standard for the general public established by the National Council on Radiation Protection and Measurement is 170 mrems/year.

9. The federal government has established a radiation exposure limit on uranium fuel cycle facilities including uranium mining, milling, fuel fabrication, power plants and waste disposal. Under this radiation standard, the general public is not to receive more than 25 mrems/year exposure.

10. In the United States there are approximately 311,000 naturally occurring cancer deaths per year. The lifetime risk of cancer death for a population exposed to 100 mrem (average U. S. background radiation level) is 0.9 to 4.8 deaths per 100,000 deaths in the population.

11. Epidemiological studies of uranium miners indicate the incidence of lung cancer is greater than expected for the general population and is estimated to be 13 cases per one million workers per year.

12. There is an occupational exposure risk associated with working in a uranium mine and mill. Under present standards with 5,000 rem/year maximum worker exposure limit, 4.5 to 24 deaths in 10,000 deaths would be expected to occur as a result of occupational exposure to radiation.

B. Uranium Exploration

1. Uranium exploration in the Upper Peninsula over the past 30 years has centered in eight counties (Baraga, Chippewa, Dickinson, Gogebic, Iron, Marquette, Menominee and Ontonagon). To date, surface and subsurface drill hole exploration has not resulted in a commercial uranium deposit and results indicate the uranium occurrences are small localized with uranium concentrations of less than 1.0 percent.

2. The majority of the world's known uranium reserves are in Precambrian rocks. The Precambrian age rocks of the Upper Peninsula presents a similar geologic environment and it is assumed that the potential for economic uranium deposits exist in Michigan. However, in most places the Precambrian rock is under a deep cover of glacial drift material which increases the difficulty for exploration and mine development.

3. Uranium exploration drilling on public and private land is subject to regulatory control of local units of government (county, township, municipal) through the power of zoning established by the County Rural Zoning Enabling Act (P.A. 183 of 1943).

4. Uranium exploration drilling on public and private land is subject to regulatory control in Michigan through the Mineral Wells Act (P.A. 315 of 1969).

5. There is a provision in the Michigan Wells Act which exempts a test well driller from the necessity of obtaining a permit prior to drilling test wells in areas with Precambrian rock directly underlying unconsolidated surface deposits. Since the areas of interest to uranium companies in the Upper Peninsula primarily include Precambrian rock with unconsolidated surface formations, a permit is not required.

C. Uranium Mining, Milling and Reclamation

1. Even if an uranium ore body is discovered in 1982, whether on private or public land, a uranium mine will not start up immediately in the Upper Peninsula. The decision to initiate a uranium mining operation is dependent on economic as well as geologic factors. The Federal

Trade Commission studied the economic structure of uranium industry and concluded it takes 8 to 12 years from initial exploration to commencement of mining as representative of the average time period.

2. At the local level, uranium mining and milling is subject to local zoning authority under the County Rural Zoning Enabling Act (P.A. 183 of 1943).

3. At the state level, uranium mining and milling is subject to state control under Part 135 of the Public Health Code (P.A. 368 of 1978), but this is limited to the mine wastes and uranium ores and does not include the uranium product (yellowcake) or the uranium mill tailings which are regulated by the federal government.

4. At the state level, radioactive air and water pollutants from uranium mines and mills are subject to regulation under the Public Health Code (P.A. 368 of 1978) to insure that the off-site concentrations do not exceed state exposure limits.

5. At the state level, non-radioactive air and water pollutants released into the atmosphere, surface or groundwaters of the state from a uranium mine and mill is subject to the state Air Pollution Act (P.A. 348 of 1965) and Water Resources Commission Act (P.A. 245 of 1929).

6. At the state level, radioactive mill tailings are specifically excluded from regulation under the Hazardous Waste Management Act (P.A. 64 of 1979), but non-radioactive solvents and certain chemicals may fall under regulation of this Act.

7. At the state level, mine reclamation is subject to the Mine Reclamation Act (P.A. 92 of 1970, as amended) for only open pit mines. Shaft mines are exempt from regulation under this Act.

8. At the federal level, uranium mining and milling is subject to the Atomic Energy Act of 1954, the Resource Conservation and Recovery Act of 1976 and the Uranium Mill Tailings Radiation Control Act of 1978. Uranium mines and mills must receive a federal license prior to mining and milling.

9. At the federal level, exposure of miners to radioactive contaminants from uranium mining and milling is subject to the federal Mine Safety and Health Act of 1977.

10. At the federal level, mine reclamation is subject primarily to the Uranium Mill Tailings Radiation Control Act of 1978.

CONCLUSIONS

A. Uranium Exploration

1. The Mineral Wells Act provides a sufficient basis to regulate uranium exploration drilling and promulgation of additional legislation is not necessary.

2. If uranium exploration permits are written to insure proper site preparation, mud and drilling pit construction, casing of the drill hole, cementing of the hole upon completion of data collection and sufficient soil coverage of mud pits and site restoration, the radiological and environmental impacts will not pose a health risk to the general public.

3. The exemption for obtaining a permit in areas of Precambrian rock with unconsolidated surface formations should be reviewed in light of uranium exploration. It does not provide for the prior review of a specific drilling plan nor allow for the inclusion of specific safeguards in a permit. The driller is under no obligation to identify the proposed well location or disclose his drilling, cementing or abandonment procedures for up to two years after drilling the hole. Thus, it is difficult for the regulatory agency to know the location, inspect the well site and operations carried out to determine if they are sufficient to prevent surface or underground waste.

   In light of the public concern over uranium exploration, it would be proper for the health and welfare of the general public to require submission of permit applications for uranium exploration in the Precambrian rocks. It would appear that the statute gives the supervisor the power to set aside the existing permit exemption through the execution of a special order to control pollution or eliminate a hazardous condition. It appears a public hearing before the supervisor and the mineral well advisory board is required to take evidence on the need for the exemption.

4. Notwithstanding the conclusion that uranium exploration does not pose a significant health hazard to the general public, it is recognized that individual members of the public will remain unconvinced or skeptical. If uranium exploration is going to continue to be permitted and not prohibited by legislative action, it is recommended that the uranium mining companies improve their public relations with local government officials, landowners and general public. It is our opinion that attempts by companies to conduct their activities in a secretive manner will only contribute to the fear and suspicions of the public. An open and public exchange of questions and answers will aid in seeking a resolution.

5. The moratorium on leasing of state owned mineral rights for uranium exploration in the Upper Peninsula should be lifted.

6. Local units of government should review existing zoning ordinances and develop appropriate land use plans and ordinances for uranium as well as other metallic mineral exploration.

B. Uranium, Mining, Milling and Reclamation:

1. The ability to eliminate or minimize adverse public health and environmental impacts of uranium mining is keyed to three factors: the existence of sufficiently stringent regulatory laws, the ability of local state and federal agencies to effectively administer those laws and conscientious self-monitoring by the uranium industry.

2. Presently, there is a regulatory framework in existence and uranium mining in Michigan would be subject to the requirements contained in these statutes. There are at least four federal, six state and one local statute which apply to one or more aspects of uranium exploration, mining, milling and reclamation.

3. There is not within the existing regulatory framework in Michigan a statute that addresses uranium mining in a comprehensive manner or any other metallic mineral mining.

4. In the case of uranium, the federal government has enacted the Uranium Mill Tailings Radiation Control Act of 1978 that incorporates a comprehensive review of uranium mining, milling and reclamation.

5. With respect to uranium mining, the Governor and Legislature have four options available either individually or in combination to regulate it.

   a. Maintain the status quo and use existing federal and state statutory framework to regulate uranium mining.

   b. Obtain federal delegation from the Nuclear Regulatory Commission for administration of Uranium Mill Tailings Radiation Control Act of 1978 as an agreement state.

   c. Legislatively enact a comprehensive mining statute for Michigan to cover uranium mining as well as other metallic mineral mining.

   d. Establish a formal Board of Inquiry to review site-specific uranium mining proposals and make findings and recommendations to the Governor on approving or restraining specific uranium mining projects. (This should be designed along the lines of inquiries conducted in Australia and Canada).

6. The implementation of agreement for state delegation for the administration of the Uranium Mill Tailings Radiation Control Act of 1978 from the Nuclear Regulatory Commission or the enactment of a state metallic mineral mining statute will require several years effort.

7. Until there is an indication of a commercially feasible uranium discovery and project proposal, the state need not initiate extension manpower or financial appropriations to implement the options identified in B-5. In light of the observation that a long lead time is necessary (4-6 years) in developing a uranium mining operation once an ore body is discovered, there would be sufficient time to provide for an orderly and open public review and legislative action relative to uranium mining, milling and reclamation.

8. The state need not become a federal agreement state now. There is an existing state and federal regulatory framework in place. A final determination on agreement status should be undertaken if uranium exploration indicates the development of an uranium mine is highly likely rather than a remote possibility.

9. Local units of governments could review existing zoning ordinances and consider appropriate zoning regulations for uranium mining and reclamation.

10. This report does not address the social and ethical question to the uranium controversy. While the matters of a factual nature in this dispute can be elucidated and resolved through scientific and engineering studies, the social and ethical values in dispute do not reside solely with the scientific and engineering community and administrative bodies. These are matters whose resolution lies within the political forum.

1. INTRODUCTION - PROPOSED METALLIC MINERAL LEASE

In 1980, the Department of Natural Resources (DNR) held two public hearings in Marquette and Lansing, Michigan, on July 17 and 24, respectively to receive public and industry comment on a proposed metallic mineral lease. The public hearings attracted approximately 300 people at Marquette and approximately 30 people at Lansing. The majority of those in attendance and providing public comments at Marquette were residents of the local communities, property owners, county and state elected officials. Out of the 64 speakers, there were only four industry representatives. The hearing in Lansing was attended primarily by industry representatives with 10 of 12 speakers representing industry's viewpoints. The public hearings very clearly identified two issues:

1. A significant difference of opinion existed between the mining industry and general public on the need for and the hazards associated with uranium exploration, mining and milling in the Upper Peninsula. Consequently, the mining industry favored the leasing of state land for uranium exploration and development and the public generally opposed it on state and private lands.

2. The mining industry and majority of the general public did not find the proposed lease instrument acceptable for adoption.

The stimulus for drafting the proposed lease was an unprecedented number of mining industry requests to lease state owned mineral rights for metallic mineral exploration and development in the Upper Peninsula. The applications were received by the department from 1975 through 1980. However, they did not come in at a uniform rate. The first applications, received in 1975, totalled only 17,361 acres. Then, in a six month period (January-June 1976) additional applications brought the total number of acres to 268,000. By the end of 1976 that total reached 460,000 acres. Since January of 1977, however, some applications have been withdrawn. As of June, 1980, pending applications total 390,599 acres. The DNR had never received such a large number of requests nor had as many acres nominated for metallic mineral leases.

In fact, mining industry interest in state lands in the Upper Peninsula in the last 40 years has been relatively low. Although the state owns approximately two million (19%) of the 10.5 million acres in the Upper Peninsula, the DNR, as administrator of state owned mineral rights, had leased only 87,659 acres for metallic mineral exploration and development, including leases for iron, copper and uranium. At the time most of these inquiries were submitted (1975 to 1977), about 3,900 acres were under lease for copper, iron and other metallic minerals.

Most of the 141 mineral leases entered into by the state between 1943 and 1976 granted the right to explore and develop only a single mineral. Industry was usually interested in a single target mineral, such as copper or iron. The present industry interest in a spectrum of metallic minerals within a single lease is a new development.

These industry applications were also significant not only for the acreage requested, but also because of the mineral of interest. A number of applications identified uranium as the target mineral. Historically, there had been very little interest in uranium in Michigan. Of the 141 mineral leases granted, only 11 were for uranium exploration and development (Table 1).

Table 1. A summary of mineral leases issued by the Department of Natural Resources from 1944 to 1976, the acres leases and under lease as of December 31, 1979

Type of Lease	Lease Activity	Leases Granted	Leases Active	Acres Leased	Acres Under Lease (12-31-79)
Iron	1944-1967	73	3	33,682	200
Uranium	1948-1962	11	0	1,115	0
Copper	1953-1972	26	9	11,306	3,263
Metallics	1965-1973	31	3	41,556	440

These were issued between 1948 and 1962. Uranium discoveries were limited, no mining development occured and all the leases expired. Apparently, the uranium mining industry shifted its efforts in the United States to the western states, where uranium exploration in the 1950's and 1960's led to commercial mining development.

Presently, there are mining industry applicants interested in leasing state land for uranium-thorium. Other applicants are also interested in acquiring state leases to explore for minerals other than uranium, including nickel, lead, zinc, manganese, gold, copper, iron and molybdenum. Their interest centers on state mineral ownership in Marquette, Iron, Baraga, Dickinson and Menominee counties. Out of the 390,559 acres of interest for leasing, 384,982 acres (98.6%) are located in these five counties with the remainder (5,577 acres) located in Chippewa, Gogebic and Ontonagon counties (Table 2 and Figure 1).

Table 2. State mineral ownership (acres) requested by mining industry for leasing in the Upper Peninsula as of June, 1980.

County	Number of Townships	Fee Ownership	Mineral Only Ownership	Total
Marquette	23	91,007	39,532	130,539
Dickinson	8	91,190	14,741	105,931
Iron	19	38,937	38,346	77,283
Baraga	17	40,305	17,883	58,188
Menominee	5	11,003	2,038	13,041
Chippewa	3	2,405	0	2,405
Gogebic	5	0	2,632	2,632
Ontonagon	2	0	540	540
	82	274,847	115,712	390,559

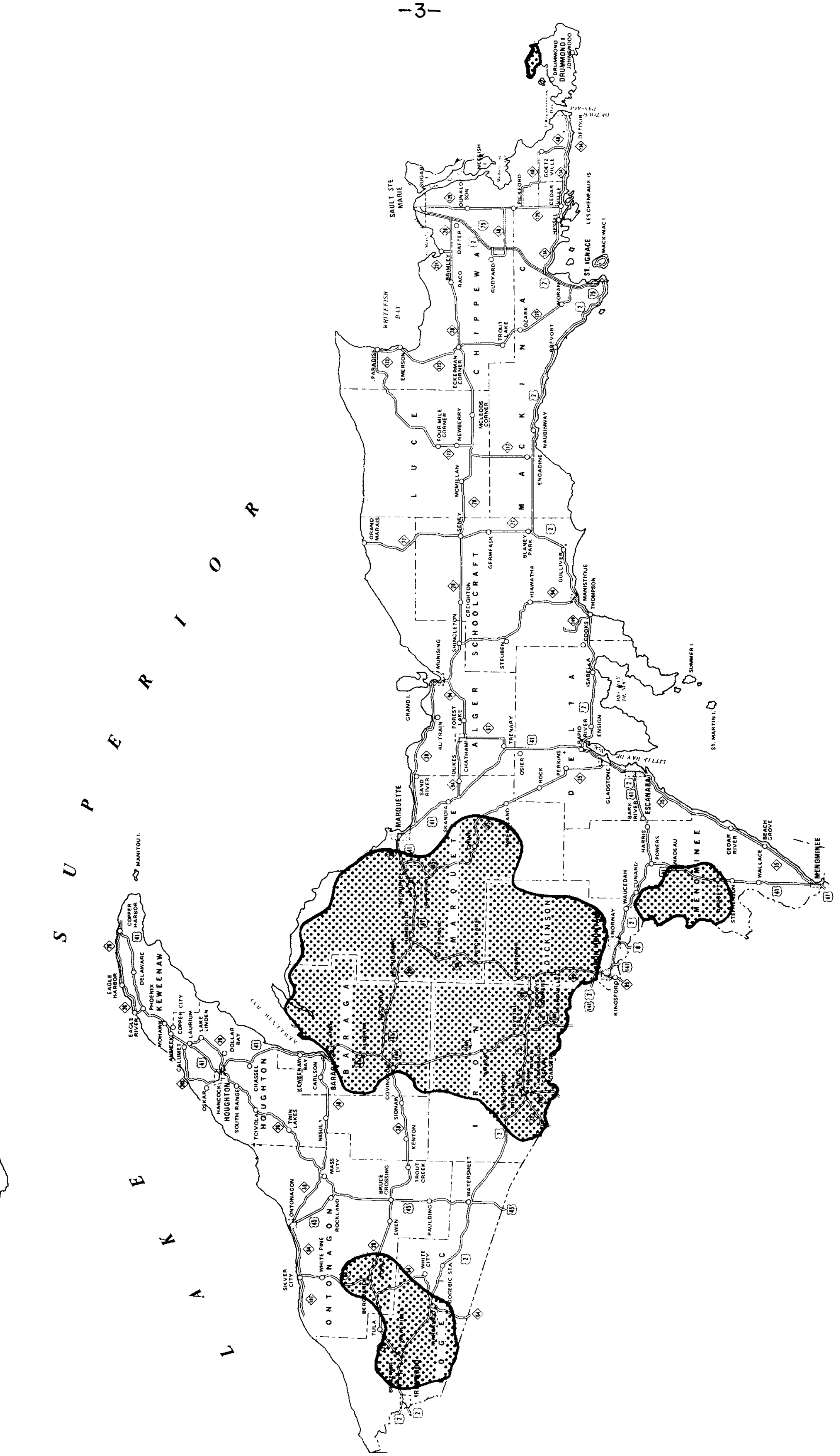


Figure 1. General area of interest in Upper Peninsula of Michigan to the metallic mineral mining industry for acquisition of state mineral leases.

A. PUBLIC RESPONSE TO PROPOSED LEASE

A central question surfaced as a result of industrial and environmental organizations comments at the public hearings: Is a lease solely an economic instrument or can it include environmental provisions as well? Industry averred that the lease should be solely an economic document between the parties. It should not include environmental protection provisions whose inclusion is redundant, since federal and state environmental and public health legislation exists to provide environmental protection and assure worker safety. They pointed out that any metallic mineral exploration and mining, whether conducted under state, federal or private mineral leases, must be done in compliance with all applicable federal, state and local statutes and rules. Additionally, they noted that a number of environmental permits will be required in any mining development, and that each has a specific permit review process with provision for public input and review prior to a federal or state agency decision to approve or deny the permit. They also point out that often an environmental impact assessment (EIA) or environmental impact statement (EIS) is required by law.

For example, at the federal level, the National Environmental Policy act of 1970 places a duty on federal agencies, including the Environmental Protection Agency (EPA) and the Nuclear Regulatory Agency (NRC) to consider the overall environmental impact of a project requiring a construction and/or operating permit under specific federal statutes administered by these agencies. Correspondingly, at the state level, under the provisions of the Michigan Environmental Protection Act of 1970 (MEPA) state regulatory agencies have a duty, in weighing the merits of issuing or denying a permit under specific legislation, to consider the environmental and health impacts beyond the narrower limits of each permit application. That is, an agency must read the specific statute in concert with the MEPA in arriving at a decision.

Further, since 1974, under the direction of the Governor's Executive Order 1974-4 creating the Michigan Environmental Review Board, the state agencies in carrying out their own projects or granting approval to projects proposed by the private sector must consider the overall environmental impact. They can, at their discretion, declare a project to be a major state action and require the preparation of an environmental impact statement by the project's sponsors as part of the permit review. And, as a check against an agency acting arbitrarily in its decision to declare a project a major or minor state action, the Michigan Environmental Review Board can, in the presence of substantial public controversy, petition the Governor to direct the agency to declare the project a major state action and prepare a environmental impact statement. And, to ensure public review all major actions must be submitted to the MERB for its review prior to the issuance of any state permits associated with the project. Thus, industry believes there is a sufficient regulatory framework in place to address site specific environmental issues and to provide for public input.

While the public and environmental representatives did not comment directly on the relationship between the proposed lease and the existing environmental-public health regulatory framework in place at the federal and state level, they did share with industry representatives a fear of uncertainty over future mining activities for the life of any metallic mineral leases entered into by the state. While there is no factual dispute over the existence of environmental and public health statutes in place, there is disagreement between industry and environmentalists over the degree of protection provided. The environmental comments express concern in two areas; first, in the adequacy of standards contained in the statues and second, in the ability of the federal and state agencies to adequately monitor specific mining activities, obtain compliance with permit conditions and pursue enforcement in a timely manner.

Since environmental legislation, like all legislation, is forged in the political arena, it is subject to future amendatory action. Concern was expressed that environmental controls incorporated to date in regard to mining are not lost at some time in the future. Thus, the commenting environmentalists view it desirable to include certain environmental provisions as part of the state metallic mineral leases. Thus, one of the two major concerns expressed at the public hearings focuses on the inclusion or exclusion of environmental protection clauses in the proposed state leases.

B. Public Response to Inclusion of Uranium in Proposed Lease

However, equally predominant, if not the main concern of general citizen and environmental speakers, was the propriety of allowing uranium exploration, mining and milling in the upper peninsula under any conditions. Speakers in favor of and in opposition to the granting of state mineral leases for uranium stated their position with emotion. It was clear to the DNR representatives conducting the hearing that polarization was evident and achieving a mutually acceptable solution to all parties would be, to say the least, difficult. As the proposed lease was drafted, it granted the right to the Lessee to explore and develop any uranium or thorium discovered in or upon the leased land. Those opposed to uranium exploration and mining expressed the view that the state should not include radioactive elements in any state metallic mineral leases. Specifically, they expressed the following concerns:

1. It was submitted that development of uranium mining in the Upper Peninsula would aid in the proliferation of nuclear weapons. It was further stated that Michigan by consenting to uranium exploration and mining would be, if not directly, at least tacitly approving the expansion of the global nuclear arms race. It was also opined that warfare is immoral and the state, by allowing uranium exploration and mining, would be acting immorally.

2. It was submitted that the development of uranium mining would aid in the development of the nuclear power industry. A belief was stated that nuclear power generation involves substantial public risk due to the possibility of accidental releases of radioactivity and the generation of high level radioactive wastes. It was also feared that expansion of the nuclear power industry involves increased risk of nuclear war as a result of the availability of plutonium produced in reactors for use in the production of atomioc explosives. It was expressed that the risk of nuclear sabotage and theft by terrorists and criminal groups would be enhanced through uranium mining development.

3. It was submitted that the exploration for uranium would release radon gas to the atmosphere in the process of coring and drilling when an uranium ore bearing formation was encountered. The concern was expressed that "interrupting the integrity" of the earth's crust would increase the possiblity of uranium and randon contamination of groundwater and drinking supplies. Thus, the exploration activity would pose a health risk to workers, visitors to areas of exploration drilling and residents on adjoining property.

4. It was submitted that past monitoring of exploration core holes by the state on private and state land had been inadequate to protect the public health.

5. It was submitted that the past disposal of low and high level uranium tailings by industry had created public health hazards and environmental contamination in the western United States and Canada. It was also expressed that containment of uranium tailings required isolation for decades and even centuries due to the long half life of the radioactive waste. There was concern that the funding and regulatory monitoring of the tailings containment structures would be inadequate to ensure integrity of the containment site and prevent air, surface and groundwater contamination.

6. It was submitted that the intrusion of uranium mining (industrial development) in the Upper Peninsula was incompatible with the recreational, wildlife and forestry values of the area.

7. It was submitted that the economic benefits in direct employment, secondary employment, taxes and royalty revenue generated by uranium mining would not outweigh the social and environmental losses.

8. It was submitted that radon poses the principal radiation hazard in uranium mining and, in the past, workers have experienced health problems and death as a result of exposure to radon in the process of mining and milling the ore.

9. In light of recent discoveries of contamination of soil, ground and surface water in Michigan (Hooker Chemical Company, Muskegon County) and elsewhere in the United States (Love Canal, New York), it was submitted that little trust existed in the mind of the public that governmental regulatory bodies can or will effectively monitor uranium mining projects to protect the public health and envionment from radiation hazards.

10. It was also submitted that the public wanted absolute assurance that an accident would not occur during or after the completion of uranium mining that would lead to exposure of public and envionment to a radiation hazard.

In addition to the positions expressed against leasing of public land for uranium mining, a review of the hearing tapes reveals six distinct positions relative to uranium exploration and mining on either public or private land in the Upper Peninsula:

1. There were positions of absolute opposition to uranium exploration, mining and milling in the Upper Peninsula under any condition on moral, philosophical and religious grounds.

2. There was a position of conditional opposition to uranium exploration, mining and milling due to past industrial and governmental errors that led to radiation exposure of workers, general public and environmental contamination.

3. There was position of support for uranium exploration, mining and milling in the Upper Peninsula based on the improved governmental safety and environmental regulations and improved industrial awareness, which should greatly reduce or eliminate the likelihood of repeating the uranium mining errors noted in the 1950's and 1960's.

4. There was a position neither in opposition nor in support of uranium exploration and mining at this time, but in light of the past and present environmental and public health impacts, these individuals were interested in reviewing more data before taking a position. They favored a careful, thoughtful public review prior to any decision.

5. There was a position in opposition to uranium exploration and mining, but not opposition to the state entering leases for nonradioactive metallic minerals.

6. There was a position in opposition to the state entering any leases for any type of mining.

As a result of the DNR public hearings and the corresponding news coverage, knowledge of the potential for uranium exploration and develepement in the Upper Peninsula became more widely known. More citizens became concerned with possible public health and environmental impacts associated with uranium mining. They spoke and wrote to their elected officials at the local, state and federal level in late July and August, 1980. They commented that they were unaware of the potential prior to the hearings. Uranium mining had never occurred in Michigan, but they had read or heard of environmental and public health problems with existing uranium projects in Canada and the western United States. There were confused and worried about the development of uranium mining in the Upper Peninsula.

Further, four local units of government in the Upper Peninsula adopted resolutions opposing the leasing of state land for uranium exploration and mining (Table 3). They requested immediate suspension of all negotiations on the lease until open public hearings are held in each county and also sought the cessation of uranium exploration on private and public land by all

companies and individuals. They received support from the Charlevoix county Board of Commissioners in the Lower Peninsula.

Table 3. Local units of government that adopted resolutions indicating opposition to the leasing of state land for uranium exploration and mining.

Local unit of government	Date of Resolution
Delta County Board of Commissioners	August 12, 1980
Township of Bates - Iron County	August 13, 1980
Charlevoix County Board of Commissioners	August 13, 1980
Township of Portage - Houghton County	August 14, 1980
Baraga County Board of Commissioners	October 14, 1980

Not all local units of government voiced formal opposition to uranium leasing. Marquette, Dickinson, Iron and Menominee counties (four of the five counties with state land of interest to mining companies) did not, to the state's knowledge, take a formal position. Also, the state is not aware of any formal position taken by other township boards within the eight counties of interest (Table 2).

In addition to units of government, the Marquette Area Chamber of Commerce (July 15, 1980) and the Ishpeming Chamber of Commerce went on record in support of mineral leasing by the state and expressed concern over the lease as drafted. It is their position that the lease as written was a disincentive to mineral development rather than an incentive. They encouraged resumption of negotiations to develop an acceptable lease. Also, the Michigan State Chamber of Commerce, by resolution of its Board of Directors (October 28, 1980), supported the leasing of state owned minerals in 1981 immediately following the release of the report to the Governor. The Chamber also supported the inclusion of uranium in the lease while the Upper Peninsula Environmental Coalition (UPEC) adopted a resolution in November of 1980 to oppose exploration and mining for radioactive materials in the Upper Peninsula. This resolution contains the following nine reasons for their opposition.

1. It is an established fact that ionizing radiation is harmful to living tissues.

2. While dangers associated with exploration appear to be minimal, little systematically collected data on radiation levels at drilling sites have been gathered to confirm this theoretical assumption.

3. Likewise, no systematically gathered background radiation data exist for present conditions in the Upper Peninsula with which to make comparisons.

4. Without a defined policy, particularly on private lands, there appears to be little citizen control over whether radioactive materials, if discovered in commercial quantities, are mined and processed.

5. With regard to mining, the record of corporations and government regulatory agencies in controlling radioactive tailings in Ontario and New Mexico has been poor, resulting in environmental damage and human illness.

6. There has been practically no experience with uranium mining under the soil and moisture conditions existing in the Upper Peninsula.

7. The economic benefit for residents of the Upper Peninsula do not appear to offset the potential health and environmental risks involved.

8. The use of uranium for electrical generation represents a continued philosphy of dependence upon non-renewable sources and detracts from necessary efforts to develop renewable energy sources.

9. Mining and concentrating radioactive materials contribute to a growing unresolved global problem of radioactive waste disposal.

C. Governor's Response To Public Concern

On August 14, 1980, Governor Milliken, in a news release, directed the departments of Public Health and Natural Resources to study the potential environmental and human health risks associated with uranium exploration and mining. Although each department had some expertise and knowledge of the properties and effects of radioactive elements, neither had direct administrative experience with uranium mining. Due to the absence of uranium mining in Michigan, it had not been necessary to establish a regulatory program. However, it was recognized that the questions raised at the public hearings required an answer. In order to assure citizens in the Upper Peninsula that state lands would not be leased prior to completion of the study, the Governor directed that state lands not be leased for uranium mineral rights.

In addition, the Natural Resources Commission in August of 1980, in responding to objections over the language in the proposed metallic mineral lease, directed staff to enter once more into negotiations with the mining industry to seek a mutually acceptable metallic mineral lease instrument. The meetings should include representatives from environmental interests who had expressed concern over the proposed lease as well. These negotiations were to be conducted while this study was being prepared.

D. Scope Of The Report

It is within this controversial framework that this report enters. The likelihood of this report resolving the issues at hand is remote. The resolution of the uranium controversy is clearly in the political arena. The

ultimate decision or decisions involve the weighing of factual, social and ethical issues. Perhaps this is best expressed by the Australian Commission of Inquiry in 1977 in its Ranger Uranium Environmental Inquiry Report (1). The three-member Commission, appointed by the Prime Minister, noted that:

> "ultimately, when the matters of fact are resolved, many of the questions which arise are social and ethical ones. We agree strongly with the view, repeatedly put to us by opponents of nuclear development, that, given a sufficient understanding of the science and technology involved, the final decisions should rest with the ordinary man and not be regarded as the preserve of any group of scientists or experts, however distinguished."

This report will address two issues.

1. A review of the potential environmental and human health impacts relating to uranium exploration, mining and milling.

2. A review of the existing federal and state law in place to regulate uranium exploration, mining and milling.

In doing so, it is necessary to point out that this report is prospective in nature. Uranium exploration activities currently underway in Michigan are at the early stages of mineral exploration. There are no uranium mines in the state. No state-owned lands are under lease. Thus, this report is generic in scope and not site specific. We view this report as a guide to aid in framing the issues and identifying the existing regulatory controls on uranium mining. It is our hope that it will educate and thereby aid in the timely resolution of the uranium controversy through the political process.

II. URANIUM MINING CONTROVERSY

A. Eastern States

Social controversy over the question of uranium exploration and mining in the Upper Peninsula should not be considered a phenomenon limited to Michigan. In the late 1970's, the uranium mining industry had become interested in the eastern United States and was actively seeking leases and conducting exploration programs in several states, including Virginia, New Jersey and Vermont. However, local opposition resulted in industry interest falling off on exploration along the eastern seaboard. Towns in New Jersey and Vermont passed restrictive ordinances and Vermont requires legislative approval prior to the operation of any uranium mine (2).

Closer to home, this controversy was voiced not only in Michigan in 1980, but in Wisconsin and Minnesota as well. As in Michigan, the controversy surfaced in response to ongoing or proposed uranium exploration on private and state lands. And, as in Michigan, neither Minnesota nor Wisconsin presently lease state land for uranium exploration. The Minnesota legislature in 1980 passed a statute which placed a moratorium on the leasing of state owned mineral rights for uranium until July 1, 1981. It also directed the Minnesota Environmental Quality Board to prepare a report describing what regulatory controls are necessary for uranium exploration and uranium mining by the same date (3). In a separate, but related action, the Legislative Commission on

Minnesota Resources provided $25,000 to the Minnesota Department of Natural Resources in 1979 to prepare a report on the possible environmental impacts of uranium mining and milling in Minnesota. This report was completed in June, 1980. It was not site specific and drew no conclusions on whether uranium mining or milling should or should not be conducted in Minnesota (4).

Wisconsin, after much legislative debate, did not adopt a resolution in opposition to uranium exploration and mining. But, as in Minnesota, the legislature did adopt a statute to regulate the drilling of core holes for uranium exploration (5). Both states are also conducting monitoring programs to measure the randon release from uranium exploration drilling activity (4,5).

B. Western States

This shift in public attitude on uranium mining, whether well founded or ill perceived, has also occurred in the western states. Public objection to uranium mining surfaced in Montana and South Dakota in 1980. Opponents of uranium mining called for a legislative ban. The issue was put before the voters in the fall of 1980. Montana adopted a citizen referendum banning the disposal of radioactive waste material in Montanna from uranium mining and nuclear power facilities. It did not ban uranium mining, only the disposal of by-products (tailings) in Montana (6). A citizen initiative in South Dakota placed on the ballot a proposal to require a statewide vote prior to the issuance of any state permits for each proposed uranium mining project. This proposal was defeated (7).

Not all the opposition to uranium mining is related to radiation hazards. For example, in the South Dakota Black Hills, an arid region with limited water resources, farmers, ranchers and local communities also view the development of uranium mines as another demand on the water resources of the region (2).

Historically, the greatest production of uranium in the United States has occured in the western states of New Mexico, Colorado, Texas, Utah and Wyoming. The production from the 280 openpit and underground mines accounted for 90 percent of the U.S. production. The United States, as of 1975, was the leading producer of uranium. It accounted for 45 percent of world production. Throughout the early 1970's uranium exploration and development was expanding. This was stimulated, to a large extent, by forecasts on the expansion of nuclear power plant programs. For example, in 1977 the U.S. had 69 operating nuclear power plants and federal government forecasts estimated an additional 100 reactors would be operating in the late 1980's. Since virtually all uranium mined in the U.S. is sold to government and public utilities, the expansion of uranium mining looked promising (2,8).

New Mexico was the center of U.S. uranium production. In 1977, it supplied approximately half of the nation's processed uranium and 18 percent of the world output. But, as of August, 1980, one-fifth of New Mexico's uranium miners were laid off. According to a wall street Journal article of August 26, 1980, the uranium boom is collapsing in New Mexico due to "falling prices and uncertainty over the future of nuclear power since the Three Mile Island accident last year" (8).

C. Australia and Canada: Two Examples

The worldwide governmental response to the uranium mining controversy is varied. The examples covered here should not be considered selected or slanted to represent or favor a particular viewpoint or outcome. They are not meant to be inclusive of all governmental response worldwide. They are merely illustrative. An exhaustive study was not conducted.

Australia

In 1970, Peko Mines Ltd. and Electrolytic Zinc Company of Austral Ltd. conducted a joint aerial survey over the Ranger area in the Northern Territory of Australia approximately 220 kilometers east of Darwin. This survey detected radiation anomalies and follow-up investigations confirmed the presence of rich uranium deposits. In 1975, the Commonwealth Government through the Australian Atomic Energy Commission entered into a joint venture with these companies to mine the ore and export the yellowcake (composed of 90% U_3O_8) to other nations.

In July of 1975, the Prime Minister and Minister of State for the Environment, under the authority of Environment Protection (Impact of proposals) Act of 1974 directed that an inquiry be conducted on the proposed Ranger Uranium Mine. Under the regulations of the Act, a three member commission was appointed to carry out the inquiry. The commissioners were provided with nine advisors with expertise in various aspects of mining, ecology, public health, economics and law. (1) The inquiry was called, under the Act, to receive comments and make findings and recommendations to the Prime Minister and Minister of State for the Environment on approving or restraining uranium mining at the Ranger project site. All evidence was submitted by witnesses under oath at public hearings with each witness subject to cross-examination by any other witness upon approval of the commission. The commission could also receive written verified statements and could receive evidence in private when satisfied it was desirable to do so in the public interest.

The Commission of Inquiry was required to work within the following framework:
"The Commission is required to inquire:
in respect of all the environmental aspects of:
(a) the formulation of proposals;
(b) the carrying out of works and other projects;
(c) the negotiation, operation and enforcement of agreements and arrangements;
(d) the making of, or the participation in the making of, decisions and recommendations; and
(e) the incurring of expenditure, by or on behalf of, the Australian Government and the Australian Atomic Energy Commission and other authorities of Australia for and in relation to the development by the Australian Atomic Energy Commission in association with Ranger Uranium Mines Pty Ltd of uranium deposits in the Northern Territory of Australia."

The Environmental Protection (Impact of Proposals) Act of 1974 provided the Minister of State for Environment with the discretionary authority to require the preparation of an environmental impact statement by the proponents of a project and make the document available for public comment. An environmental impact statement was prepared, notices placed in newspapers and public hearings held in seven cities.

The Ranger Uranium Environmental Inquiry is divided into two reports. The first dealt with generic issues not covered in the site specific EIS. The first report considered whether "the use of uranium in the nuclear power industry carried with it risks and danger of such a nature and magnitude that Australia should not export it, or mine it at all." The hearing for the first report began on September 9, 1975, and concluded in August of 1976. A total of 281 persons gave evidence and 354 exhibits were submitted. The transcript of evidence covered 12,575 pages.

The second report dealt with the array of issues intimately associated with the site specific mining proposal as identified in the EIS. With respect to the second report, 303 witnesses presented evidence and 419 exhibits were received. The total transcript covers 13,525 pages. The cost as of April of 1977 was over $800,000.

The first report was submitted to the government in October, 1976, and the second in May, 1977. The inquiry and preparation of the report covered 22 months. The two reports are 206 and 415 pages, respectively. The transcript record exceeds 26,000 pages.

Whatever the merit of this inquiry, its scope was wide and encompassed virtually all aspects of the uranium controversy. For example, the first report addressed the following items:

The Basics of Nuclear Power
The Present Status of Nuclear Power
World Energy Consumption
Energy Resources
The Contribution of Nuclear Power to World Energy Requirements
Uranium: Supply and Demand
Benefits and Costs of Exporting and No Exporting
Hazards of the Nuclear Fuel Cycle
Environmental Hazards of Non-Nuclear Energy Sources
Safeguards Against Diversion to Weapons-making
Nuclear Theft and Sabotage
Weaknesses of the Nonproliferation Treaty (NPT) and of the Safeguards System

The Commission developed 15 findings and recommendations with respect to the generic issue. They, like the issues raised, are broad in scope. Throughout the recommendations, there is the clear recognition of the need for continual diligence and precaution in the development of Australian uranium mining policy. The recommendations were advisory only. While approving the continuation of uranium mining development in Australia, it also called for the development of a national energy policy with the development of energy conservation and full research and development on energy resources other than fossil fuels and nuclear fission.

In its second report the Board of Inquiry ruled on the adequacy of the EIS and potential site-specific impacts of the projects.

"The Ranger project as proposed, and in the land use setting which was assumed, should not in our view be allowed to proceed. On the other hand, if the plan we propose is accepted, and the various matters we recommended in relation to it, and to the mining operations themselves, are carried out, the adverse environmental consequences of the proposal can be kept with acceptable limits. Every step in our recommendations is designed to ensure that a reasonable accomodation is reached between the proposed mining venture and the conflicting environmental values and interests."

The Ranger uranium project was authorized, but a number of limitations were placed on it to minimize adverse environmental and public health impacts.

Canada: Saskatchewan

In Saskatchewan, Canada, at about the same time (1976-1977) as the Australian Ranger Uranium Site Board of Inquiry was in process, the Minister of Environment asked the Saskatchewan Cabinet for a public inquiry on an uranium mine proposal submitted to the Department of the Environment by Amok Ltd. Amok Ltd. proposed to develop a mine in northern Saskatchewan near Cluff Lake. Saskatchewan already had two existing uranium mines at Uranium City and Rabbit Lake, but public opposition was raised over development of Cluff Lake project (9).

On February 1, 1977 the Cluff Lake Board of Inquiry was appointed. The Inquiry conducted formal and local hearings. The formal hearings were conducted in 5 months (April-September 1977) in Regina and Saskatchewan. The actual hearings required 67 days of direct testimony from 138 witnesses. The hearing record produced 10,786 pages of testimony plus 556 pages of summations.

After the formal hearings were held, local hearings were held at 23 locations throughout Saskatchewan to receive citizen input in contrast to the technical and scientific evidence presented by scientific experts at the formal hearings. These hearings were held between October 3 and 27, 1977 and attended by about 1,268 persons with 30 organizations and 260 individuals presenting comments.

Prior to the local hearings a public information and education program was developed. It included 25 town hall meetings where a speaker in favor and in opposition to nuclear power presented their respective viewpoints and the audience could ask questions of each. It also included radio and television presentations similar to the town hall format. Other efforts were made to stimulate public interest in the nuclear issue and make readily accessible to the public any information obtained during the course of the inquiry.

As part of the Inquiry and to allow public interest groups to participate in the Inquiry's formal hearings, 100,000 dollars was provided as grants to those groups lacking funding. A Financial Review Panel was established to review proposals from public interest groups and recommend which groups should be funded.

The Cluff Lake Board of Inquiry were to conduct the inquiry under the following obligations:

1. review all available information on the probable environmental, health, safety, social and economic effects of the proposed uranium mine and mill at Cluff Lake;
2. facilitate the provision of information to the public;
3. receive public comment on any matter related to the proposed development, including the social, economic and other implications of expansion of the uranium industry in Saskatchewan;
4. determine if the measures proposed by Amok Limited to protect environmental quality meet the requirements of Canadian and Saskatchewan law, regulations and policies and to report on the adequacy of such laws, regulations and policies;
5. determine if the measures proposed by Amok Limited to safeguard health and safety meet the requirements of Canadian and Saskatchewan law, regulations and policies and to report on the adequacy of such laws, regulations and policies; and
6. recommend to the Minister of the Environment whether the project should proceed, should not proceed, or proceed subject to specified conditions.

In the conducting of the Cluff Lake Inquiry, the Board:

1. will receive briefs, both written and oral, from individuals and organizations;
2. will organize and conduct public hearings in such places as the Board believes necessary to allow the public a reasonable opportunity to present their views;
3. will arrange for the proceedings of the hearings to be recorded and transcribed, and no later than November 1, 1977, the Board will:
   (a) prepare a report of its findings and recommendations; and
   (b) forward its report and a transcript of the proceedings of the public hearings to the Minister of the Environment."

As a result of the formal and local hearings which included 13,524 pages of transcript and 377 exhibits, a report entitled "Final Report: Cluff Lake Board of Inquiry" was completed (May 1978) and submitted to Minister of Environment with a recommendation to proceed in developing the uranium mine provided specific environmental and public health standards were followed.

A significant conclusion centered on the adequacy of laws and policies and the ability of the regulatory agencies to effectively enforce the laws as stated in the following findings of the report.

"Adequate standards, adequate proposed methods to meet the standards, and adequate laws to enforce the standards will not be sufficient to protect the workers at the proposed Cluff Lake mine and mill unless:

(a) Amok strictly complies with its undertaking to implement those proposed methods, and
(b) those laws are rigorously enforced by the appropriate regulatory agencies, namely The Atomic Anergy Control Board and the Occupational Health and Safety Division of the Department of Labour of Saskatchewan.

Whether the laws are rigorously complied with, and whether sufficient inspections will be carried out to ascertain if (and to ensure that) Amok strictly complies with its undertaking as to methods, will depend in large measure upon the number of competent personnel the Government of Saskatchewan makes available to the Occupational Health and Safety Division to properly and fully carry out the duties cast upon that Division by the law."

Both the Ranger Inquiry in Australia and the Cluff Lake inquiry in Saskatchewan, Canada are well documented examples of extensive public review on the uranium issue and worth reviewing directly for those who wish to go beyond the scope of this report.

Canada: British Columbia

In addition to the previous studies, the government of British Columbia initiated a similar type of inquiry on the question of uranium mining and its related environmental, health and social issues. The inquiry was established in January, 1979, but it did not complete the review. In February, 1980, the British Columbia Cabinet voted to terminate the inquiry and by statute placed in effect a seven year moratorium on uranium development in the province. As of this date, the moratorium is still in effect and no legal challenges have been made on it (10).

D. Nuclear Power Controversy and Uranium Mining

The uranium mining industry's future in New Mexico and elsewhere in the U.S. is closely linked to the future of the nuclear power industry. In fact, many in the uranium mining industry believe it is too closely linked in the eyes of the public. For example, the disposal of high level radioactive nuclear power plant waste, an issue of substantial controversy for the past two decades, affects the uranium mining industry. They believe that if the nuclear waste disposal issue is not resolved, uranium mining will continue to shrink rather than expand in the United States (8). They also see the environmental issues surrounding nuclear power production spilling-over onto uranium mining. They find that a burden is placed upon them to not only explain their actions, but those that relate to the nuclear power fuel cycle in general.

In addition to the market place uncertanties facing uranium mining and the social controversy over nuclear power generation, a shift in public opinion is occurring or has occurred in the western states with active uranium mines (8). For example, environmental, public health and worker safety issues in New Mexico have emerged. The rupture of United Nuclear's tailings dam near Gallup, New Mexico in 1979 spilled tons of radioactive material into the Rio Puerco River and on a nearby Navajo reservation (11). In a review of this accident, the Nuclear Regulatory Commission found that the contamination of ground water presented a long-term problem. In light of this incident, and other published reports of problems with containment of uranium tailings, the New Mexico government has tightened waste regulations and raised the taxes on the industry (8).

While uranium mining is still occurring in the western states and most residents do not oppose it, the complex socioeconomic-legal issues are far from resolution. In recent years law-suits have been filed in New Mexico to halt or limit uranium mining (8). Opponents of nuclear power generation view the blocking of uranium mining (on the front end of the nuclear fuel cycle) and blocking of nuclear waste disposal (on the tail end of the nuclear fuel cycle) as a means to slow down or stop nuclear energy development.

Proponents of uranium mining see this criticism from segments of the public as an overreaction. They contend that uranium mining, when measured against other types of mining, industrial and commercial activities carried out in the United States, is no more or less of an environmental or public health risk. While conceding there are potential adverse environmental and public health impacts, there are technological and engineering solutions through properly designed and operated facilities. While the uranium mining industry questions the magnitude and impact of past accidents associated with uranium mining used by environmental organizations to illustrate their opposition, they generally do not deny them, but point out the increased federal and state regulatory programs now in place in response to those incidents. From a long-term public health aspect, it is postulated by supporters of uranium mining and nuclear power generation that nuclear power should be viewed as a means of cleansing the earth of radioactivity.

This reasoning is described by Bernard L. Cohen in a June, 1977 Scientific American article (12).

"If one is to consider the public health effects of radioactivity over such long periods, one should also take into account the fact that nuclear power burns up uranium, the principal source of radiation exposure for human beings today. For example, the uranium in the ground under the U.S. is the source of the radium that causes 12 fatal cancers in the U.S. per year. If it is assumed that the original uranium was buried as securely as the waste would presumably be, its eventual health effects would be greater than those of the buried wastes. In other words, after a million years or so more lives would be saved by uranium consumption per year than would be lost to radioactive waste per year.

The fact is, however, that the uranium now being mined comes not from an average depth of 600 meters but from quite near the surface. There it is a source of radon, a highly radioactive gaseous product of the decay of radium that can escape into the atmosphere. Radon gas is the most serious source of radiation in the envionment, claiming thousands of lives in th U.S. per year according to the methods of calculation used here. When this additional factor is taken into account, burning up uranium in reactors turns out to save about 50 lives per million years for each year of all-nuclear electric power in the U.S., more than 100 times more than the life that might be lost to buried radioactive wastes.

Thus on any long time scale nuclear power must be viewed as a means of cleansing the earth of radioactivity. This fact becomes intuitively clear when one considers that every atom of uranium is desitined eventually to decay with the emission of eight alpha particles (helium nuclei), four of them rapidly following the formation of radon gas.

Through the breathing process nature has provided an easy pathway for radon to gain entry into the human body. In nuclear reactors the uranium atom is converted into two fission-product atoms, which decay only by the emission of a beta ray (an electron) and in some cases a gamma ray. Roughly 87 percent

of these emission processes take place before the material even leaves the reactor; moreover, beta rays and gamma rays are typically 100 times less damaging than alpha-particle emissions, because their energies are lower (typically by a factor of 10) and they deposit their energy in tissue in less concentrated form, making their biological effectiveness 10 times lower. The long-term effect of burning uranium in reactors is hence a reduction in the health hazards attributable to radioactivity."

However, opponents to nuclear power production disagree with this position. They content that the health impact calculations of uranium mining and tailing disposal by nuclear industry proponents do not take into account future deaths from nuclear-generated electricity. This line of reasoning is described by David Dinsmore Comey in a September 1975 Bulletin of the Atomic Scientists article (13).

> "Last year an article in the Bulletin by Bernard L. Cohen opened with the above provocative statements. The health impact of 50 deaths per gigawatt-year from coal-fired plants was almost entirely due to sulfur oxides released from the plant stack. The health impact of 0.01 deaths per gigawatt-year from a nuclear plant came from radioactive effluents released during normal plant operation, and assumed there would be no deaths from nuclear plant accidents. Other compairsons by nuclear proponents have reached similar conclusions...
>
> ...How could such enormous health effects have been overlooked? Probably because almost everyone has focused on emissions from the nuclear power plants and virtually ignored the other end of the uranium fuel cycle ..."

The other end of the uranium fuel cycle is the mining, milling and tailings disposal. It is his position that uranium mine tailings will be responsible for at least 394 deaths per gigawatt-year instead of 0.01 deaths per gigawatt-year He also states another position on the long-term impact.

> "Based on the foregoing, it would seem to be a myth that the lethal health effects from coal-generated electricity are 5,000 times greater than the lethal health effects of nuclear-generated electricity as estimated by Cohen and others. The deaths induced by the decay of thorium-230 in uranium mill tailings alone seem to swing the statistics in the reverse direction, and further analysis of other parts of the nuclear fuel cycle may identify additional health effects that have been overlooked.
>
> The Atomic Industrial Forum, the American Nuclear Society and others may argue that very few of the thorium-induced deaths will occur during our lifetimes, and that it is unfair to make such a comparison of current deaths from coal-generated electricity with future deaths from nuclear-generated electricity. But that makes the disparity a moral issue: Do we have the right to consume electricity from nuclear fission plants for the next few decades forcing thousands of future generations to suffer the lethal consequences?"

E. Commonality of Uranium Controversy

One can observe from the formal inquiries conducted in Australia and Canada and the debate in the United States over nuclear power a commonality in the issues and viewpoints held by proponents and opponents to uranium mining. It makes no difference whether the proposed uranium mining was in Australia, Canada or the United States, the generic issues are relatively constant. For example, the following excerpt from the Australian Commission of Inquiry on the Ranger Uranium Environmental Inquiry states the issues rather well (1).

> "It was submitted that there were dangers associated with the various operations of the fuel cycle, from the mining of uranium to the production of power in reactors, that there were serious and unresolved problems concerning the disposal of radioactive wastes, that there were risks of terrorist theft and use of plutonium, and that there were increased risks of nuclear war flowing from nuclear proliferation. It was contended that the continuing development of the nuclear power industry would produce greater inequality between the developed and undeveloped countries, and that this, as well as being undesirable in itself, was likely to lead to increased international tension. It was submitted that, taken alone, some of those matters constituted sufficient ground for not mining, and that taken together they certainly did so. The central proposition was that, if Australia supplied its uranium to the industry, it would be contributing in some measure to each of those hazards and problems and that therefore it should not do so. To some extent, the argument rests simply on ethical values. In some important aspects, such as the dangers of high-level wastes, of terrorism and of proliferation, practical considerations affecting Australia arise. The submission was that mining should not take place at all, or should at least be postponed until it was clear that major problems, such as the disposal of wastes, had been overcome.
>
> "In further support of the submission, it was put that on economic grounds nuclear energy was not a satisfactory source of power, that it could only in any event offer a temporary way out of the energy problems of the countries wanting to use it, and that other sources of energy were preferable and could be developed. It was also submitted that nuclear power programs were less securely established than had been made to appear, and that there might well be a revulsion against them overseas. It was put that, for these and other reasons, the use of nuclear power would not develop as projected, with the consequence that there would be less demand for uranium and the profits would be less than predicted by the proponents and by others who support mining.
>
> "The submissions and arguments mentioned were encountered by the proponents and by other witnesses. It was submitted that often the hazards were exaggerated by opponents of nuclear power, in some respects greatly so; that the economic and social suffering

> which would occur if nuclear energy were not developed would be greater than the hazards inherent in nuclear power; that the nuclear industry in all its aspects had to date a very good safety record, not least in relation to harm from radioactivity; that the hazards concerned had been exhaustively investigated by various authorities, were well understood and were under control; that the nuclear industries in countries likely to purchase our uranium were closely regulated and supervised; that the problem of high-level wastes had been virtually overcome by the proposal for vitrification and geological disposal; that the risk of terrorist activities was recognized and guarded against; that the safeguards systems provided sufficient protection against diversion and proliferation; that the operation of nuclear power stations was cleaner and involved less risk to people and the physical environment generally than fossil fuel stations; that a number of countries needed nuclear power, and a number had become dependent on it, at least in the short term; that the governments of many countries had accepted nuclear power, and it was not to the point, even if it were correct, to say that there was a large body of opposition to nuclear power development in their countries; that there was a considerable assured market for uranium; that (according to some witnesses) there was a risk that if permission to mine was not given soon, the market might shrink and prices drop because of the projected introduction of fast breeder reactors; and that the profits to be made were very good. It was submitted that, if Australia did not supply uranium, others would, and its abstention would make no difference in kind or degree to the presence of such hazards, difficulties and problems as there were.
>
> "An argument of a different kind relied upon by the parties opposed to mining was that if Australia were to decline to mine and sell its uranium specifically because of the hazards and problems involved, and were to announce its policy to the world, this would be likely to have an important effect in restricting further nuclear development, if not in actually causing a cut-back. The answer of the proponents, and others, was that such a course would be most unlikely to have the effect sought, but that, if it were desired to improve further the position in relation to the hazards and problems referred to, this could best be done if Australia were a supplier to the industry.
>
> "The proponents, and witnesses supporting their viewpoint, took the view in relation to some matters (not including, for example, proliferation) that such risks and problems as now exist are relatively minor, are of the order ordinarily accepted in everyday living, and will in all probability be overcome before they become at all acute or serious. It would be time enough to adopt a more draconian attitude if and when it was found that they were getting serious, and appeared intractable. Their opponents took more into account the long term future, as they saw it. They were of the view that humanity should not have to suffer added risks, even if they may not be great, and that the nuclear industry should be required to demonstrate that risks, particularly from radioactivity, were virtually

negligible, before being allowed to develop any further. Associated with this viewpoint was the fear that if nuclear development was not stopped very soon, the industry would develop a momentum of its own, and be beyond effective control.

Some of the opponents placed reliance on a view that people in the developed countries should simplify their life styles appreciably, so as to decrease the demand on non-renewable energy resources such as coal, oil and nuclear fuel. The scope for energy conservation, even with existing life styles, was emphasized."

Another common thread noted is the often lack of objectivity among proponents and opponents. Although each individual believes in his/her objectivity, the zeal to persuade can often cloud personal objectivity. Again, the Australian Commission of Inquiry reflects on this factor as obsesrved in their hearings (1).

"In considering the evidence, we have found that many wildly exaggerated statements are made about the risks and dangers of nuclear energy production by those opposed to it. What has surprised us more is a lack of objectivity in not a few of those in favour of it, including distinguished scientists. It seems that the subject is one very apt to arouse strong emotions both in opponents and proponents. There is abundant evidence before us to show that scientists, engineers and administrators involved in the business of producing nuclear energy have at times painted excessively optimistic pictures of the safety and performance, projected or past, of various aspects of nuclear production. There are not a few scientists, including distinguished nuclear scientists, who are flatly opposed to the further development of nuclear energy, and who present facts and views opposed to those of others of equal eminence."

"A few of the publicists for nuclear development characterize their opponents as lobbyists or dissidents, or worse. We would wish to make it quite plain that before us the opposition has come from a wide cross-section of the general community, and we would not be prepared to conclude that their motives and methods are any less worthy or proper, or intelligently conceived, than, in general, are those of the supporters of nuclear development."

Another common factor noted in the governmental responses described here is the fact that a study, whether elaborate or simple, does not produce a clear-cut conclusion. The studies merely lay out the viewpoints and supporting data for them. The ultimate decision is still a value judgment. In these democratic nations, the decision is reached by an elected political body. Thus, faced with the relatively similar array of issues, the Saskatchewan legislative elected to pursue the development of uranium mining in that Province while the British Columbia Legislature chose to place a moratorium on uranium exploration and mining. In the United States, some states have had and continue to have uranium mining (i.e., Colorado, New Mexico) while other states have enacted partial moratoriums on uranium mining (i.e., Vermont, Montana).

Thus we see that the public controversy over uranium mining has not been limited to the United States. Uranium mining development in Australia and Canada has stirred citizen objections. The central issue elsewhere and here in Michigan is: Should the government permit uranium mining and if so, under what conditions?

III. URANIUM IN UPPER PENINSULA OF MICHIGAN

A. Uranium

Uranium is a silver white metal that consists of the three semistable radioactive isotopes; uranium-238, uranium-235 and uranium-234. It is an important energy source because fission of uranium-235 releases large amounts of energy. This readily fissionable nuclide constitutes only about 0.7 percent of natural uranium. Uranium-238 makes up most of the remaining 99.3 percent and the uranium-234 only about 0.005 percent. Uranium-238 is not readily fissionable, but under neutron bombardment it converts to plutonium-239 which is fissionable.

Uranium was discovered in 1789 by Marten Klaproth in pitchblende from a mine in Germany. The element was first isolated in 1842. Radioactivity was first discovered in 1896 and radium, a daughter of uranium decay, was discovered by the Curies and Bemont in 1898 in pitchblende from Joachinsthal, Czechoslovakia, where the mineral had been known since 1727.

In the early 1900's radium became important in medical therapy. This led to a search for the ore as a source for radium. The first important sources of radium besides Czechoslovakia were the uranium-vanadium sandstone deposits in western Colorado and eastern Utah and from 1898-1923 about 275,000 tons of ore were produced. This ore yielded about 200 grams of radium, 2,000 tons of vanadium and a small but indeterminate amount of uranium. Most of the uranium went into the tailings basins.

In 1913, the U.S. deposits were supplanted as the source of radium by the large and rich Shinkolobew vein deposit in the Belgium Congo. In 1933 production began from another vein deposit, the Eldorado at Port Radium, Northwest Territories, Canada. Thereafter, the market was shared by Canada and the Belgium Congo. Only minor amounts of uranium-vandium sandstone ore were mined from 1924-1935.

In 1936, mining of uranium-vandium ores increased markedly owing to increased demand for vandium. In anticipation of the development of controlled nuclear fission, the United States in 1940 began to recover uranium from tailings discarded during the radium and vandium operations and by the end of 1947, a total of 1,440 tons of uranium oxide (U_3O_8) had been produced. In addition, the U.S procured about 10,150 tons of U_3O_8 from outside sources, mainly Canada and the Belgium Congo (14).

Uranium has a number of commercial and research uses. However, the predominant commercial use is as a nuclear fuel for civilian power reactors. It is also used in U.S. government nuclear programs including weapons, propulsion, underground tests, research and development and space applications.

Relatively small quantities of depleted uranium are used in specialized non-energy applications because of the unique properties of elemental uranium. This form, depleted in the fissionable isotope and therefore not suitable for nuclear use, is one of the most dense metals. It readily alloys with other metals to form stable compounds and is easily fabricated. Only about 10 percent of the annual industrial demand for uranium involves these nonenergy applications.

Because of its higher density, depleted uranium is better suited than lead and other dense metals for gamma-ray and x-ray shielding. Containers made of depleted uranium for radioactive materials require less weight and provide better protection. They vary in size from a few pounds to many tons.

Density and ease of fabrication make depleted uranium particularly suitable for missle ballast, for control surface balancing and counterweights in aircraft and space vehicles, and for payload simulation in test space vehicles. Castings are made in a variety of shapes and sizes, weighing up to several hundred pounds.

Depleted uranium also has a number of other nonenergy uses. Research and development on structural and mechanical properties of depleted uranium by the U.S. Army Materials Command resulted in demand for ordinance use. Uranium alloys, particularly with molybdenum and titanium, are useful for a wide range of military applications, including equipment parts, ammunition and special purpose artillery shells.

Early uses of uranium were in the chemical, ceramic and glass industries. A uranium-antimony oxide catalyst is used in the plastics industry for the production of acrylonitrile. Uranium is also used as a colorant in glass and ceramics and in steel and nonferrous metallurgy. In the electrical industry it is used for targets in x-ray tubes, electrodes in ultraviolet light sources and resistors in incandescent lamps (15).

There have been several surveys for radioactive minerals in the Northern Peninsula and analytical results have been reported in various ways. For example, the amount of uranium may be reported as percent uranium (U), percent uranium oxide (U_3O_8), percent uranium oxide equivalent (eU_3O_8), or as parts per million (U_3O_8) ppm.). Equivalent refers to measurement on a mechanical device that measures total radioactivity which could include uranium plus thorium plus radioactive potassium. The radioactivity of groundwater is normally reported in parts per billion (ppb.).

B. Geologic Occurrence

Uranium in Michigan has only been found in the western part of the Northern Peninsula. The bedrock geology of this area consists of a thick series of diverse and complex rocks combined under the general name of Precambrian. These rocks are characterized by their extreme age. Radio-metric dating indicates they were formed between 3.5 and 1.0 billion years ago. Michigan's Precambrian rocks have been and remain an important source for iron ore and copper. These rock formations are exposed throughout eight counties in the western Northern Peninsula, an area of approximately 8,900 square miles. These Precambrian rocks are divided into the Lower, Middle and Upper Precambrian based on specific events which occurred over geologic time.

LOWER PRECAMBRIAN

The oldest rocks (Figure 2) are principally submarine lavas and pyroclastics with minor sediments. Pyroclastics are made up of varying sizes of volcanic debris consisting of rock fragments and ash. The Lower Precambrian volcanic rocks have a low radioactive background. A few sample analyses have been reported and these indicate a content of less than 2 parts per million (p.p.m.). A prominent sedimentary series of rocks in central Dickinson County contains layers of lenses of quartz-pebble conglomerate. It has been postulated that the conglomerate may have some potential for uranium, but no data is available.

The Lower Precambrian volcanic rocks are intruded by granitic rocks (Figure 2) of various compositions. Where the granitic rocks have assimilated pre-existing volcanics and sediments they are called gneisses. The granitic rocks were emplaced in two stages approximately 3.5 and 2.7 billion years ago.

A number of anomalous radioactive prospects have been located in the granitic rocks. For the most part they are thin fracture fillings and local in extent. Selected samples are as high as 0.11 percent uranium. In a recent regional study, 58 widely scattered samples indicate a range of 2--35 ppm uranium (16).

MIDDLE PRECAMBRIAN

Middle Precambrian rocks in Michigan (Figure 3) are a thick succession of sediments and volcanics, principally conglomerate, quartzite, dolomite, slate, iron-formation, volcanic lavas and associated pyroclastics. The Middle Precambrian has been subdivided into four groups which, from oldest to youngest have been named the Chocolay, Menominee, Baraga and Paint River Groups and are illustrated on Figure 4. The Chocolay and Menominee Groups now occur in widely separated ranges or districts. The Baraga Group covers the largest area and is more contiguous. The Paint River Group is contained in a completely isolated basin. Middle Precambrian deposition began some 2.1 billion years ago and ended some 1.9 billion years ago.

Chocolay Group

Figure 3 depicts the distribution of rocks and Table 4 shows the rock type and maximum thickness of individual rock layers of the Chocolay Group. No anomalous uranium of significance has been reported in Chocolay Group rocks. One sample of the quartzite was analyzed and contained 10.7 ppm. eU_3O_8.

The volcanic rocks have not exhibited radioactivity above background which is less than 2 ppm.

Menominee Group

Figure 3 shows the distribution of Menominee Group rocks and Table 5 the layered rock succession, rock type and maximum thickness.

Radiometric measurement of Menominee Group rocks have not indicated exceptional radioactivity. The average is on the order of 2 to 3 ppm. The quartzite and slate have been measured at 12.4 ppm. and 6.6 ppm. eU_3O_8 in anomalous areas. The rocks indicated in black on Figure 4 represent most of

DISTRIBUTION OF LOWER PRECAMBRIAN SEDIMENTS, VOLCANICS, AND, GRANITES AND GNEISSES.

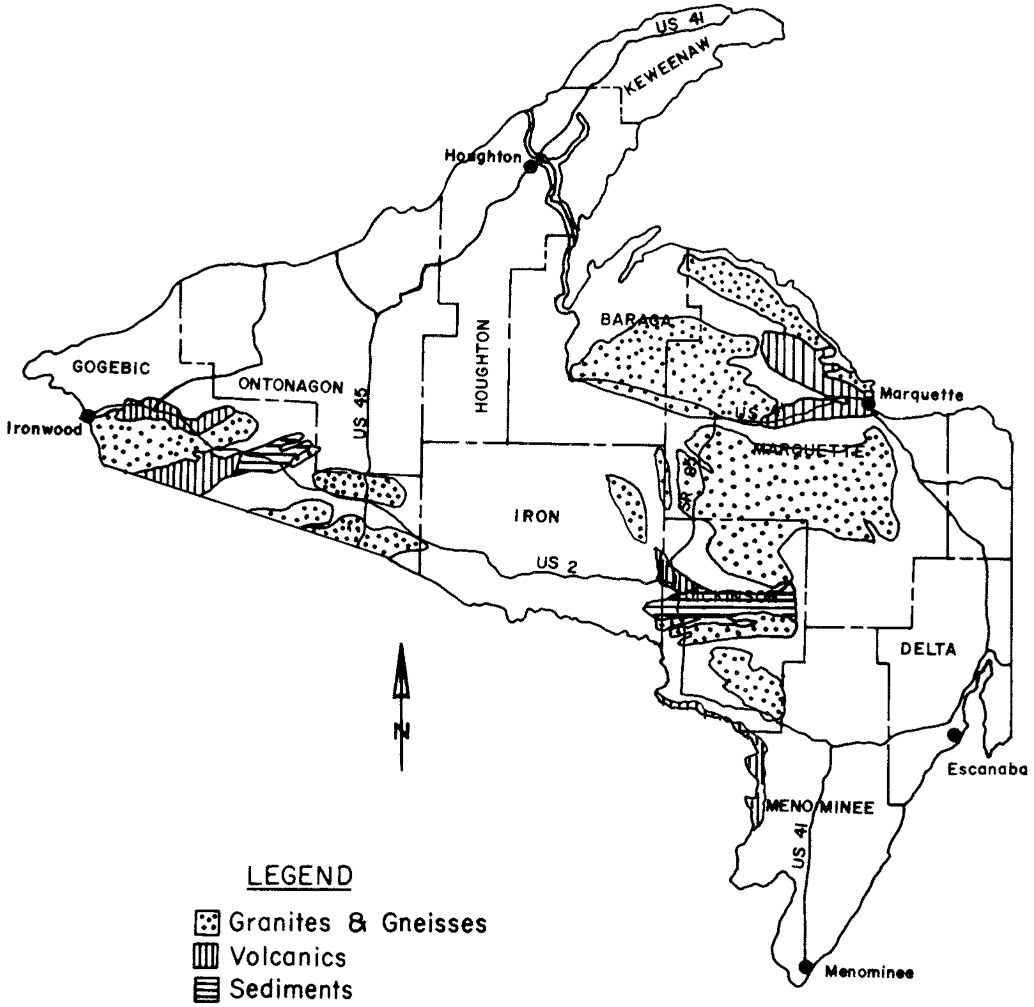


FIGURE 2

DISTRIBUTION OF MIDDLE PRECAMBRIAN CHOCOLAY, MENOMINEE, BARAGA SEDIMENTS AND VOLCANICS, AND PAINT RIVER GROUP SEDIMENTS.

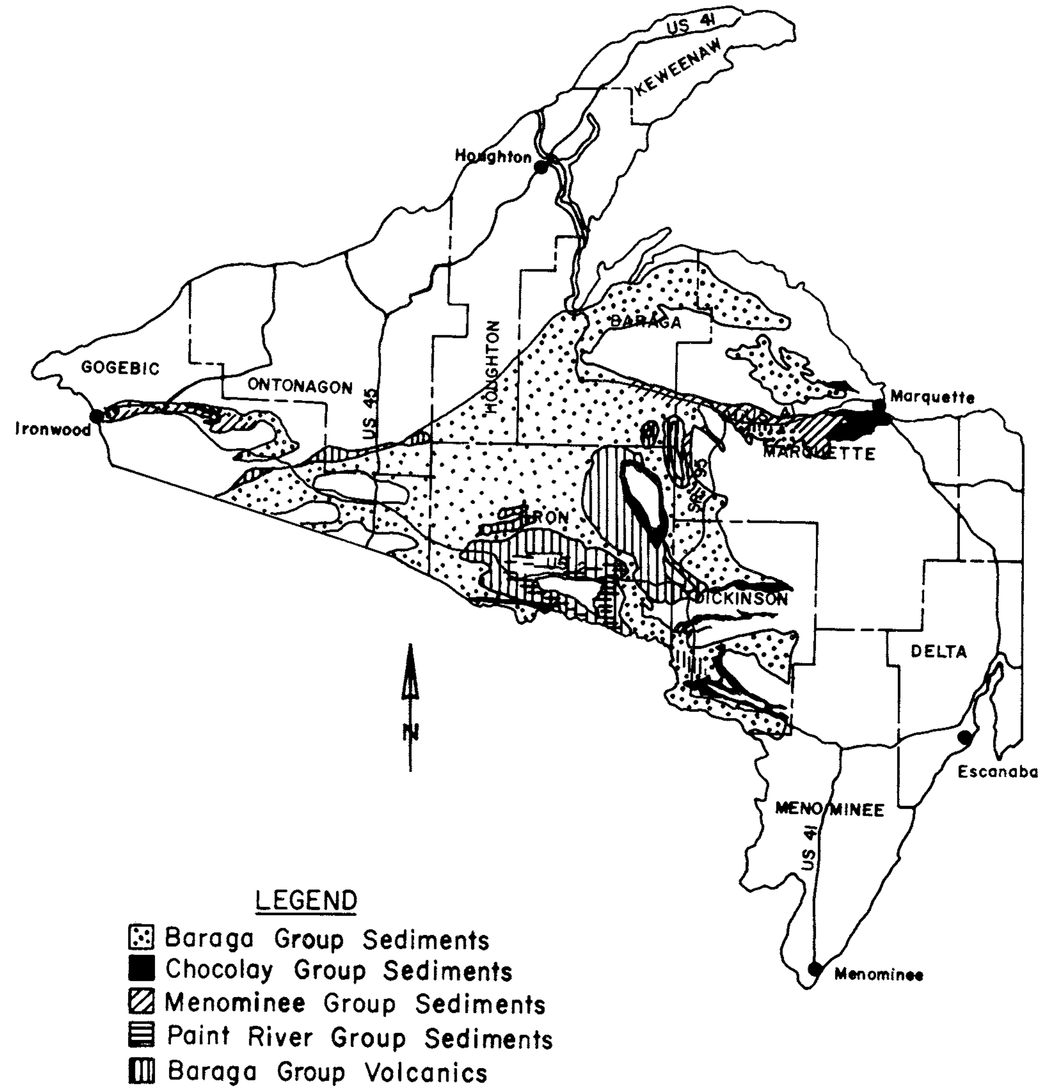


FIGURE 3

Table 4. STRATIGRAPHIC SUCCESSION OF PRECAMBRIAN ROCK FORMATIONS IN THE NORTHERN PENINSULA OF MICHIGAN

	Rock Type	Maximum Thickness (feet)
UPPER PRECAMBRIAN (Keweenawan)		
Upper Keweenawan	Sandstone	12,000
	Shale	700
	Conglomerate	6,000
Middle Keweenawan		
	Volcanics	8,000
	Volcanics	13,000
Lower Keweenawan		
	Volcanics	15,000
	Volcanics	4,400
	Quartzite	300
MIDDLE PRECAMBRIAN		
Paint River Group		
	Slate	4,000
	Magnetic Slate	200
	Graywacke	500
	Iron Formation	800
	Slate	1,500
Baraga Group		
	Volcanics and Sediments	15,000
	Slate	20,000
	Ferruginous Slate & Iron Formation	1,800
	Volcanics & Sediments	23,000
	Quartzite & Conglomerate	1,400
Monominee Group		
	Iron Formation	3,500
	Slate	3,100
	Quartzite	1,000
Chocolay Group		
	Slate	1,500
	Dolomite	2,500
	Quartzite	2,000
	Slate & Conglomerate	3,500
LOWER PRECAMBRIAN		
	Granitic Intrusive Volcanics	24,500

the major productive iron formations in Michigan. Radioactivity of the iron formations is about that of background or less than 2 ppm.

Baraga Group

Figure 3 illustrates the distribution of Baraga Group sedimentary rocks and Baraga Group volcanic rocks. Table 5 indicates the rock type succession and maximum thickness of rock units.

In the sedimentary rock sequence of the Baraga Group, the lower quartzite conglomerate layers contain relatively large amounts of monazite near Palmer, Marquette County. Monazite is a complex mineral consisting of rare earth oxides, thorium and some uranium. Analysis of whole rock samples show thorium (Th) ranging from 500 to 2,300 ppm. and uranium from 20 to 62 ppm. U. This deposit may be a potential future source of thorium. It is the largest resource of radioactive material now known in the Northern Peninsula.

The slate formation covers a very large area of the Baraga Group. The formation includes other rock types including graphitic carbonaceous slate and minor iron formations. Locally, in several areas, anomalous samples containing uranium have been located and analyzed. Along the Huron River in northern Baraga County an iron formation sample ran 215 ppm. U_3O_8. Selected drill core samples ran .009 to .0016 percent U_3O_8 and averaged .001 to .002 percent. In central Baraga County samples from an old graphite quarry contained .005 to .037 percent U_3O_8 and iron formation from the same general area contained .003 to .068 percent U_3O_8. Iron formation west of Ishpeming in Marquette County showed .001 to .034 percent eU_3O_8. Selected samples of iron formation and graphite slate from abandoned mine dumps near Gwinn in Marquette County, show up to 0.1 percent eU_3O_8. Along Green's Creek in Marquette County, northwest of Gwinn, channel samples of ferruginous slate ran 0.004-0.036 percent U. Selected samples ran up to 0.1 percent U_3O_8.

Paint River Group

Figure 3 shows the distribution of Paint River Group rocks as contained within a triangular shaped basin. Table 5 indicates the rock type and maximum thickness of the rock succession.

Anomalous radioactivity in the Paint River Group is confined to the iron formation and the underlying slate. The upper 20-50 feet of the basal slate immediately beneath the iron formation is a pyritic graphitic carbonaceous slate that contains 30 to 45 percent pyrite and 5 to 15 percent carbon. A scintillometer survey of the mines and mine waste dumps in this district revealed numerous anomalous samples of iron formation and black slate. The normal radioactive content of the unoxidized iron formation is about 0.001 percent eU_3O_8; that of the graphitic slate is higher, on the order of 0.003 to 0.004 percent eU_3O_8. The highest value analyzed was 0.513 percent eU_3O_8 from an iron mine 1,000 feet below the surface. Many other anomalous samples in this district were analyzed and contain 0.02 to 0.041 percent eU_3O_8. It must be emphasized that anomalous areas are local in extent and as far as it is now known these do not represent a minable resource.

DISTRIBUTION OF UPPER PRECAMBRIAN (KEWEENAWAN) SANDSTONE, VOLCANICS, AND NONESUCH SHALE.

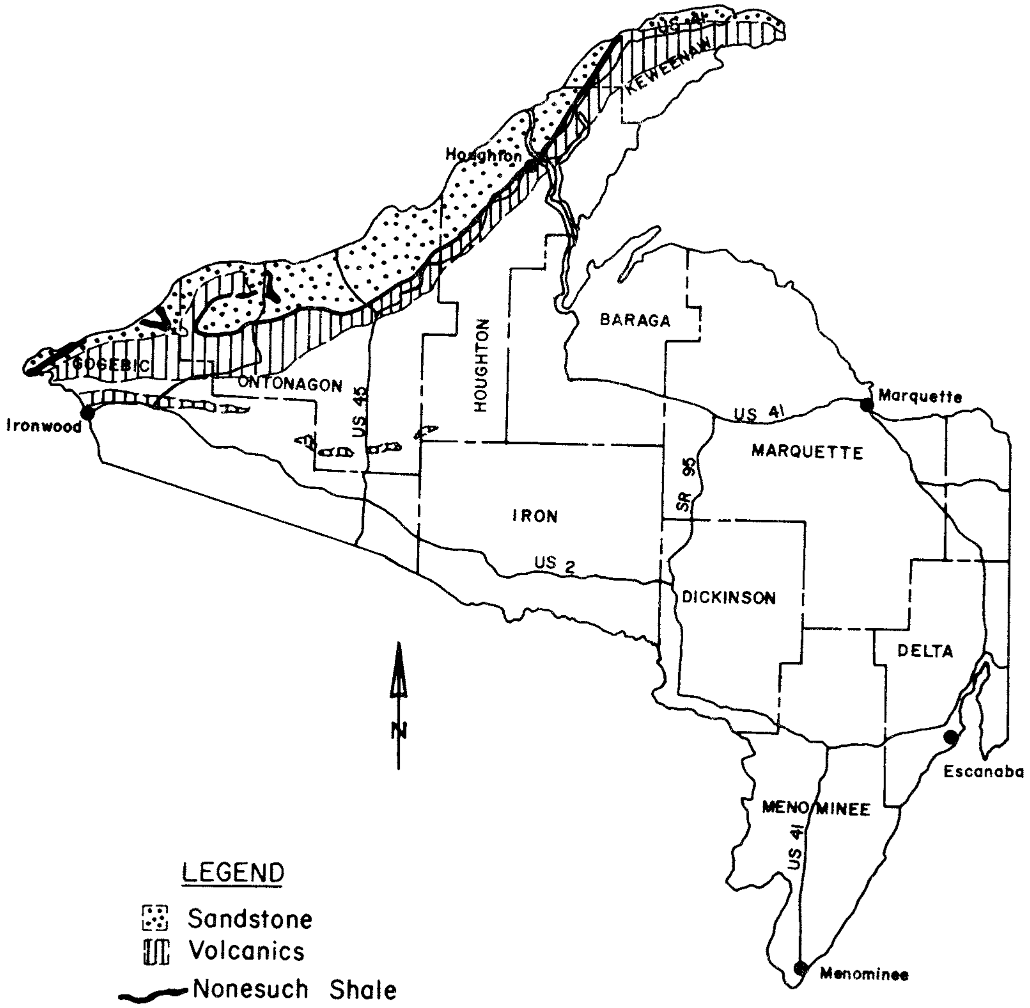


FIGURE 4

DISTRIBUTION OF UPPER PRECAMBRIAN (KEWEENAWAN) JACOBSVILLE SANDSTONE.

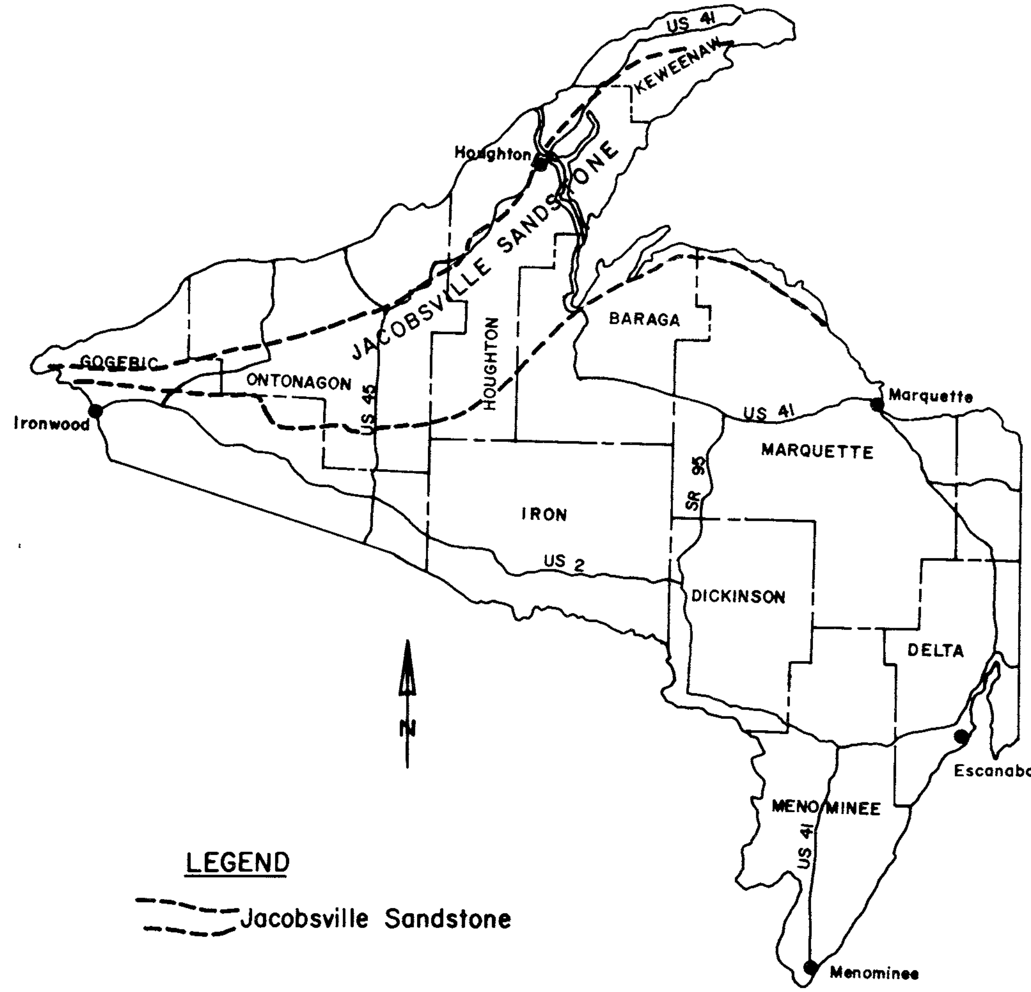


FIGURE 5

UPPER PRECAMBRIAN

The Upper Precambrian rocks of northern Michigan (Figure 4) are collectively called Keweenawan and are subdivided into Lower, Middle and Upper Keweenawan units. Keweenawan rocks are formed some 1.4 to 1.0 billion years ago and consist of four formations of volcanics and four formations of sediments with a total maximum thickness of more than 60,000 feet. Table 5 show the rock succession, rock type and maximum formation thickness.

The Upper Precambrian rocks of Michigan are a small portion of a major geologic feature which extends from eastern Lake Superior to the west and southwest into northern Kansas. This is a rift zone of volcanics and sediments named the Midcontinent Gravity High.

Lower Keweenawan quartzite and volcanics have been measured to contain less than 2 ppm. eU. Middle Keweenawan volcanics contain 3 to 8 ppm. eU in general. However, one occurrence northeast of Lake Gogebic was measured at 0.02 and .003 percent eU. One sample is reported to contain 500 ppm. eU. Upper Keweenawan shale has 0.001 to 0.003 percent eU.

Jacobsville Sandstone

The age of the Jacobsville Sandstone (Figure 5) has been a controversial subject for over 150 years. Most maps refer to this formation as Precambrian or Cambrian in age. In 1976, the U.S. Geological Survey officially designated the Jacobsville as Upper Precambrian. The Jacobsville Sandstone covers an area of approximately 1,500 square miles shown on Figure 5 and an unknown area to the east.

Scintillometer surveys and analysis have indicated that the exposed Jacobsville rocks have a very low radioactive content, less than 2 ppm. eU. However, it has been hypothesized that where the Jacobsville overlies Lower and Middle Precambrian rocks, as in parts of Baraga and Houghton counties, the geologic environment is similar to that where Proterozoic-Unconformity type of uranium ore deposits have been found in northern Australia and in northern Saskatchewan, Canada.

C. Uranium Surveys & Exploration in the Upper Peninsula

During the 1950's and 1960's, the Geological Survey Division, Department of Natural Resources field checked radioactive occurrences located by private prospectors. The occurrences were located on state-owned mineral lands. The purpose of the evaluation was to determine if such locations were valid to issue a state uranium lease. No systematic surveys were conducted by the Geological Survey.

In 1950, the U.S. Geological Survey (17) published a map of an airborne radioactivity survey for parts of Marquette, Dickinson and Baraga counties. The general conclusion drawn was that the radioactive anomalies were due to the radioactivity emanating from granitic rocks.

On April 30, 1951, (18) the Jones and Laughlin Ore Company, a wholly owned subsidiary of Jones & Laughlin Steel Corporation, contracted with the United States Atomic Energy Commission to sample and make radiometric analyses of the Precambrian sediments in the States of Michigan, Minnesota and Wisconsin. The initial purpose of the contract was to sample dark graphitic and pyrite

bearing slates. Earlier exploration by the Jones and Laughlin Ore Company in Baraga County, Michigan had indicated these materials contained a small quantity of uranium.

In the early summer of 1951 uranium mineralization was found in the iron formation. The scope of the investigation was then broadened to include not only the iron formation, but also other Precambrian rocks. Field parties equipped with Halross scintillometers visited outcrop localities, open pit iron mines and active and abandoned mine dumps and made underground tests of mine workings. Where scintillometer readings exceed two or three times background level, samples for radiometric analysis were collected. Over 2,000 radio-metric determinations for U_3O_8 equivalent were made. In addition, many chemical analyses for other elements were made by the iron ore research laboratory of the Jones & Laughlin Steel Corporation.

All data from the sampling program indicated that uranium concentrations of 0.1 percent or better are limited to (a) veins of quartz and calcite cutting black slate and (b) concentrations in iron formation associated with black slate. Veins or shear zones cutting through other types of rocks are still possibilities, but none are known and none were found by the scintillometer and sampling survey.

The best chance of such a discovery is in the oxidized phase of the Upper Huronian iron formation of the Marquette and Menominee Ranges. Outcrops of oxidized iron formation and black slate are extremely rare. Both formations are known to be widely distributed on the Marquette and Menominee Ranges, but the distribution is determined almost entirely from mine workings, drill exploration and magnetic surveys. Oxidized iron formation and black slate are not resistant rocks and their outcrop is almost entirely buried beneath glacial overburden too thick to permit instrumental detection of radioactivity. Less than one-half of one percent of the known iron formation is exposed for sampling or radiation tests. While no commercial urnaium deposits were found, the number of showings of plus 0.1 percent U_3O_8 in the limited area of favorable host rock available for testing was encouraging.

A study to evaluate geochemical methods of exploration for uranium was made in 1957 and reported in 1962 by the Atomic Energy Commission (19). About 600 water samples were collected from streams and subsurface sources in a reconnaissance survey of an area approximately 7,000 square miles comprising parts of northeastern Wisconsin and the northern peninsula of Michigan. The background value of U_3O_8 in waters ranged from less than 0.1 to 0.5 parts per billion (ppb). Anomalous samples were found in waters of a cutting through a sandstone outlier in Sections 32 and 33, T40N, R29W in Southern Dickinson County. Anomalous values of 3.2, 9.7 and 10.2 ppb. were obtained. The sandstone is probably a correlative of the Jabobsville Sandstone. Anomalous samples from wells in the Jacobsville were located in Section 2, T49N, R26W, Marquette County and the values ranged between 1.4 and 6.9 ppb. The highest sample came from a water well penetrating Lower Precambrian granite gneiss in Section 36, T41N, R29W, Dickinson County. The uranium concentration of this sample was 14.8 ppb.

Considering the scope of the problems encountered and the limitations imposed by the data acquired in this reconnaissance investigation, the following conclusions were offered:

1. Low Order of Uranium in Waters

In comparison with other areas investigated for uranium by hydrogeochemical methods in the Western regions of the United States, the uranium content and the dissolved solid content of waters in Michigan and northeastern Wisconsin is quite low. The low uranium background values suggest that geochemical anomalies in waters will likewise be of a low order due to the folowing conditions inherent to the area studied: (a) limited bedrock permeability in metamorphic terrane; (b) dilution effect of surface water runoff; and (c) rapid "fadeout" or inability of many streams to carry trace amounts of uranium over extensive distances.

2. Uranium in Bedrock and Surficial Cover

Metasedimentary rocks generally contain from 1 to 20 ppm. U_3O_8, but isolated pods of the upper iron member and a few mineralized zones of the Michigamme slate may contain as much as a few hundred ppm. Granitic rocks consistently carry uranium values ranging from 3 to 40 ppm. Surficial cover, with the exception of certain bogs, contains from 0.3 to 6.0 ppm. uranium. The U_3O_8 content of bog soils may range up to 300 ppm. The mean uranium content of sandy glacial till based on a limited number of samples in Michigan and Wisconsin is about 1.0 ppm., although individual samples may contain as much as 10 ppm.

In 1969 the Atomic Energy Commission (20) published the results of an examination of previously located uranium occurrences in the Great Lakes Region of Michigan, Wisconsin and Minnesota. The report noted large areas inadequately explored due to the sparsity of rock outcrops as a result of the extensive cover of glacial drift.

The Department of Geology and Geological Engineering, Michigan Technological University conducted studies of uranium and thorium occurrences in Precambrian rocks of Michigan and Wisconsin in 1976 and 1977 (16,21,22). The purpose was to evaluate uranium and thorium potential of the area. Uranium and thorium occurrences were reexamined. Attempts were made to relate the geologic setting of occurences to major uranium deposits of the world. The study was sponsored by the Energy Research and Development Administration (ERDA).

In early 1977, the DNR's Geological Survey Division submitted an unsolicited proposal to the U.S. Energy Research and Development Administration (ERDA) entitled "Drilling for Geologic Information in Middle Precambrian Basins in the Western Portion of Northern Michigan". In September 1977, $588,000 was awarded for the project. Drilling commenced shortly thereafter and continued into the spring of 1978. Target areas selected for drilling were basins where geologic information was lacking. Five holes were drilled in northern Marquette County and one hole in north-central Iron County.

The six diamond core holes totaled 9,896 feet. Five feet of core from every 30 feet was subjected to mineralogical and chemical analysis. In addition, each hole was logged by five down-hole geophysical methods. A total of 338 samples were subjected to analysis for nine major oxides and 27 trace elements with a total of 9,126 analyses. Uranium content ranged from 0.2 to 130 ppm. and averaged 2.5 ppm. Open-file reports of this exploration project are available from the Geological Survey Division (23-30).

In 1978, the Department of Geology and Geological Engineering, Michigan Technological University, published a study (31) sponsored by the Department of Energy (DOE). This included a detailed account of the geology and uranium resources of the Proterozoic-Unconformity type uranium deposits of Saskatchewan and Australia. The Precambrian geology of various states including Michigan were critically examined to determine the geological potential of this type deposit.

The U.S. Department of Energy (DOE), under their National Uranium Resource Evaluation (NURE) program conducted a high sensitivity airborne radiometric and magnetic survey of the entire Northern Peninsula. The objectives of the DOE/NURE, may be summarized as follows:

> "To develop and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States..."

As an integral part of the DOE/NURE Program, the National Airborne Radiometric Program was designed to provide cost-effective, semiquantitative reconnaissance radioelement distribution information to aid in the assessment of regional distribution of uraniferous materials within the United States.

Project areas are those covered by 1 degree latitude and 2 degree longitude topographic quadrangle maps. The quadrangles are those published as 1:250,000 scale topographic maps and cover an area approximately 96 miles in an east-west direction and 52 miles in a north-south direction. The surveys were conducted under contract by Geometrics, Inc. Traverse lines were flown at a spacing of 3 to 6 miles in an east-west direction with north-south tie lines 18 to 24 miles apart. Survey altitude was approximately 400 feet above ground level. Numerous maps show computer plotted readings of radioactive uranium, thorium and potassium measurements and their various ratios plus radioactive anomaly interpretation maps. In addition, the reports show histograms for the frequency of counts per second for the various soil groups. The reports cover the Hancock (32,33) and Marquette (34) quadrangles in Michigan, the Iron River (35) quadrangle, Michigan and Wisconsin, the Sault Ste. Marie/Blind River (36,37) and Cheboygan/Alpena (38) quadrangles, Michigan and the Escanaba quadrangle, Michigan and Wisconsin (39).

As a part of the NURE program, a project of hydrogeochemical and stream sediment reconnaissance basic data is being conducted by Union Carbide Corporation under contract to the DOE. Stream sediment and groundwater samples are collected and reported on a quadrangle basis as above. Values for uranium specific conductance, boron, barium, potassium, sodium, strontium, alkalinity and pH are listed and plotted on maps for groundwater samples. Results for stream sediment samples are listed and plotted for uranium, thorium, cerium, nobium, titanium, vanadium, yttrium, zirconium.

For the Iron River quadrangle, [40] uranium in groundwater ranges from 0.02 to 220 ppb. Uranium in stream sediments ranges from 0.42 to 47 ppm. In the Marquette quadrangle, [41] uranium in groundwater ranges from 0.02 to 150 ppb. Uranium in stream sediments ranges from 0.049 to 11.38 ppm. The Ashland and Escanaba reports have been released, however, they include only a small portion of Michigan. The Escanaba quadrangle report (42) indicates uranium in groundwater ranges from 0.12 to 75.0 ppb and in stream sediments from 0.27 to 5.6 ppm.

D. Uranium Occurrence Conclusion

Various surface surveys and subsurface drill hole exploration programs in Michigan over the past 30 years have not been successful in locating a commercial uranium deposit. Numerous surface and aerial radioactivity surveys have been made and exploration drilling has been conducted in Baraga, Chippewa, Dickinson, Gogebic, Iron, Marquette, Menominee and Ontonagon counties. A total of 134 holes have been drilled. Samples from uranium occurrences have indicated uranium contents up to a few tenths of one percent. However, such occurrences have been very small and localized concentrations.

A major portion of the world's known uranium reserves are in Precambrian rocks. These include the type deposits generally classified as quartz-pebble conglomerate; Proterozoic unconformity related; disseminated magmatic, pegmatitic and contact; and vein. The Precambrian age rocks of northern Michigan are lithologically diverse and structurally complex. They display geological environments and features common to the above named types of deposits. It is therefore concluded that it is realistic to assume that the geologic potential for uranium deposits of economic volume and grade exist in Michigan Precambrian age rocks. However, a limiting factor in the search for uranium in northern Michigan is the lack of surface bedrock exposure due to a deep cover of glacial deposits.

IV. ENVIRONMENTAL IMPACTS AND REGULATORY FRAMEWORK ASSOCIATED WITH URANIUM EXPLORATION

Exploration Impacts

It is known that the level of radioactivity at the drill sites may increase above the local background level in the process of drilling and sampling the hole (43). A question has been raised as to the human health significance of this radiation exposure. Individuals wonder if the increase is a radiation hazard to the workers and general public. It has been stated at the public hearings that it is and, therefore, exploration drilling for uranium should not be allowed in the upper peninsula.

Part of the opposition to the state leasing mineral rights for uranium is the fact that this will lead to more exploration drilling. This, in turn, would increase the chance of the inadvertent release of radioactive solids and gases into the groundwater supplies and atmosphere. This concern is addressed here.

Historically, the uranium industry has used drilling as an important tool in the exploration and development of uranium projects. Drilling activity has varied over the years. In 1948 surface drilling in the U.S. totaled 210,000 feet. One-hundred-thousand (100,000) uranium exploration holes were drilled in 1978 in the United States and this amounted to the all-time exploration and development drilling yearly maximum of 41 million feet. In 1979 exploration drilling totaled 26.8 million feet and represented 66 percent of total drilling (exploration and development) conducted (44).

While it is not possible to predicate the extent of future exploration drilling in the upper peninsula, it appears the use of drilling will be less than previously experienced in the western states for the sandstone

formations. In a paper presented at the Uranium Resource/Technology seminar in Golden, Colorado (March, 1980), James F. Davis made the following observations (45).

> "For all of its history, uranium exploration in the United States has been dominated by the search in the sandstone environment. Recently, however, spurred by the fantastically high grade discoveries in Australia and Canada, U.S. explorationists have been reexamining their exploration philosophies and strategies and devoting an increasing amount of time and money to the search in the so-called "hardrock" environment. The transition is slow and sometimes painful for the explorationist, as the techniques can substantially differ from exploration in the sandstone environment--the drill is replaced by geologic mapping as the primary data base source; the geologist is suddenly called upon to become a surface rather than a subsurface specialist. Instead of depositional environments, he must understand structural complexities and metamorphic gradients. Drilling is much more costly and every hole must be planned carefully. Gone is the luxury of drilling several hundred (or even several thousand) holes per year. Drill footage is no longer a measure of exploration. More money is spent on geophysics and geochemistry, as well as geologic mapping, in an attempt to best determine where the costly drill holes will be placed."

The upper peninsula of Michigan is one of those "hardrock" geologic environments.

Prior to any decision to mine uranium, an ore body of sufficient size and quality (percent of uranium oxide) must be located. Although uranium is widely disseminated throughout the earth's crust, it usually is present in relatively small quantities. However, certain geographic areas have higher concentrations of uranium. These are relatively rare. The purpose of uranium exploration is to locate these rare uranium deposits and evaluate their commercial viability.

1. Aerial Surveys

Field uranium exploration procedures include aerial and ground surveys. Aerial surveys consist of systematic flights over a defined geographic area with radiometric equipment to measure the relative gamma ray emissions from the earth. In 1969, 130,000 miles were flown with the majority of the flights in the western United States (44). Such flights measure the background gamma radiation in the earth's crust. They do not involve mechanical disturbance of the earth's crust. Consequently, there is no environmental impact associated with it other than consummation of aviation fuel and combustion thereof.

2. Ground Surface Surveys

Ground surveys involve the systematic mapping of a given area to identify the pattern of background radiation. In this manner areas with higher potential for uranium deposits are separated from areas of lower potential.

This type of survey involves the measurement of gamma ray emmissions by driving or walking over the area of interest with radiometric equipment and with electromagnetic equipment to measure the magnetic characteristics of the underlying formations. Again, as in aerial surveys, the earth's crust is not substantially disturbed. There is no increase in radiation hazard to the environment or human health. There is no disturbance of the earth's crust to alter the naturally occurring radiation fluxes emanating from it.

A ground survey will also involve the collection of water, soil and rock samples for further laboratory analysis. The collection of samples is as simple as wading into a stream to remove small quantities of stream sediment or removing small soil and rock specimens from existing geologic outcropings or abandoned mining sites. This involves a minimal disturbance of the earth's crust and poses no radiation hazard. Similar types of samples are taken routinely by foresters, aquatic biologists and geologists in carrying out their research and management programs unrelated to uranium exploration.

3. Ground Subsurface Surveys

In addition to surface sample collection, subsurface samples are often taken from the bedrock. To obtain a subsurface sample, an exploration hole is drilled. The holes are often three to six inches in diameter and can range in depth from just below the surface down to 1,200 feet (46). The specific depth can vary with each hole. Depending on the kind of samples desired, either a core or a rotary hole is drilled. Generally, the holes are vertically drilled, but the orientation can vary up to 40 degrees from the vertical position. This type of drilling is not unique to uranium exploration. It is essentially the same process as drilling water wells and similar to exploration drill holes used in the search for nonradioactive base metals.

The exploration operation is carried out in three steps; site preparation, drilling activity and site restoration. Generally, an area of 2,000 square feet is cleared to allow for operation of the drilling equipment, mixing of the drilling mud and containment of drill cuttings. Where possible, existing roads can be used to bring the equipment into and out of the drilling site. However, in some cases, off the road equipment may be used to reach a remote site or a temporary road may be constructed. If drilling is done in the winter over frozen ground, often the heavy equipment can be moved on skids without the need to construct temporary roads.

The actual drilling involves the cutting of the hole, removal of core and/or cutting samples for laboratory analysis and electrical log analysis of the hole. The drill cuttings removed from the earth in the process of drilling can be stored in small pits adjacent to the hole. Upon completion of the hole and data collection, the cuttings can be buried in the pits by covering with the topsoil removed in the process of site preparation. The site can be graded and leveled and seeded. The temporary roads removed and reclaimed to original state or are left open at the discretion of land owner. Usually, each exploration hole can be drilled in two to four days (46) including sealing of the hole.

In any drilling activity, the driller is faced with the possibility of contaminating a potable groundwater aquifer by intermixing with contaminated groundwater (naturally or man-induced) through the connection established by the drill hole. In the process of drilling the vertical integrity of the

FIGURE 6. A SIDE VIEW OF TEST WELL DRILLED INTO PRECAMBRIAN ROCK UNDERLYING UNCONSOLIDATED SURFACE DEPOSIT.

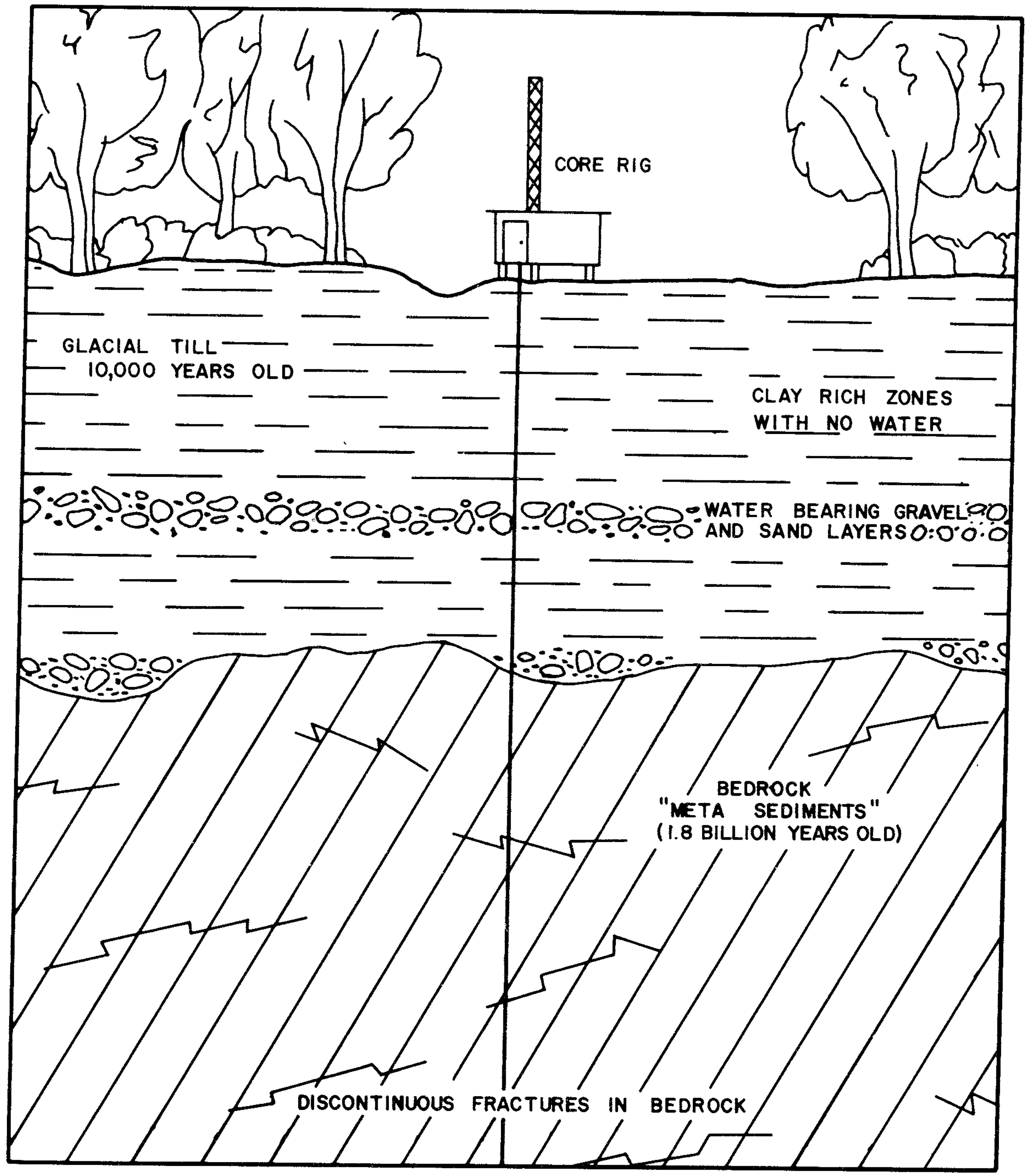


FIGURE 7. EXAMPLE OF EXPLORATION DRILLING METHOD IN UNCONSOLIDATED GLACIAL TILL.

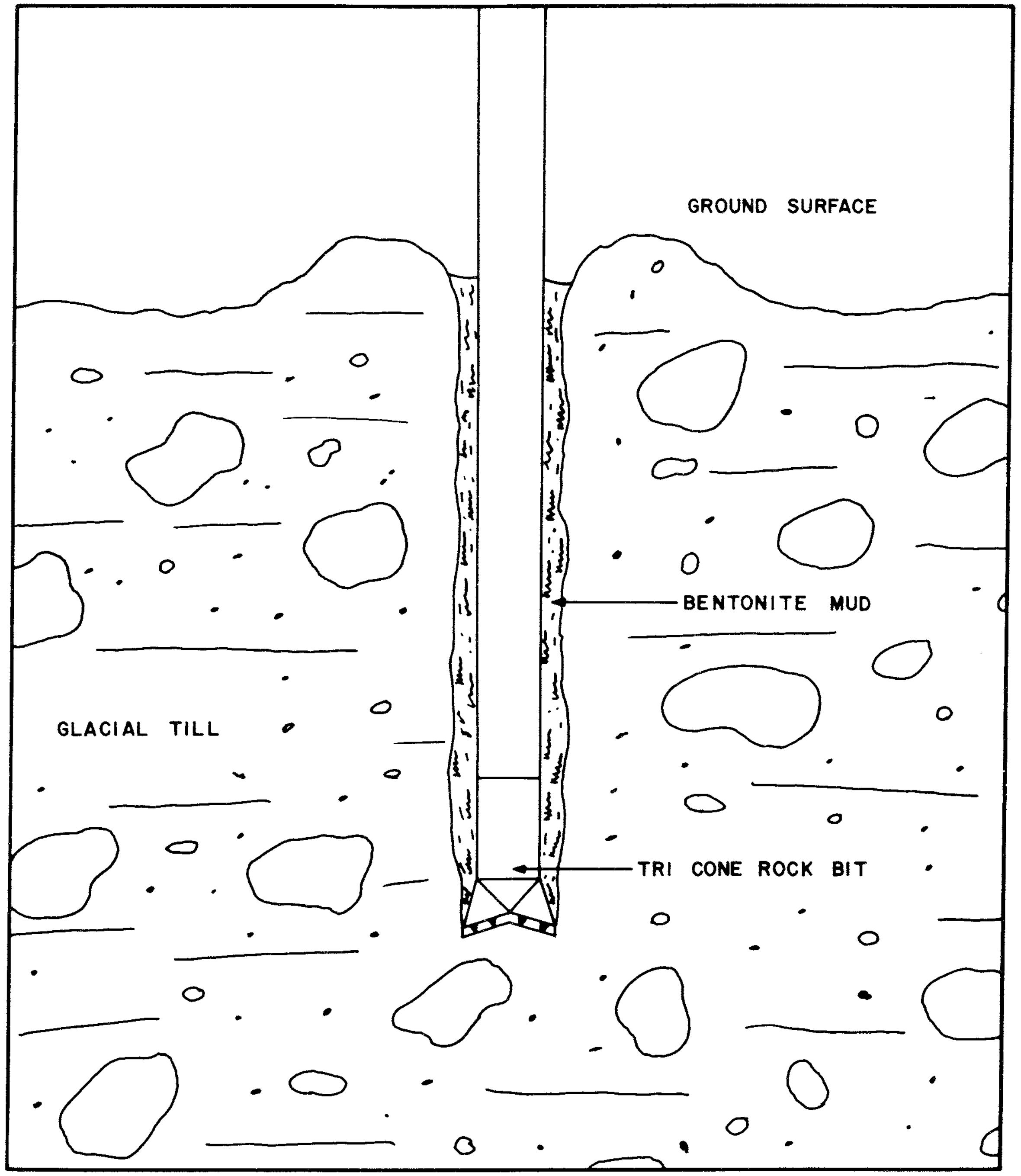


FIGURE 8. AN ILLUSTRATION OF A METHOD TO SEAT CASING AT THE GLACIAL TILL - PRECAMBRIAN BEDROCK INTERFACE.

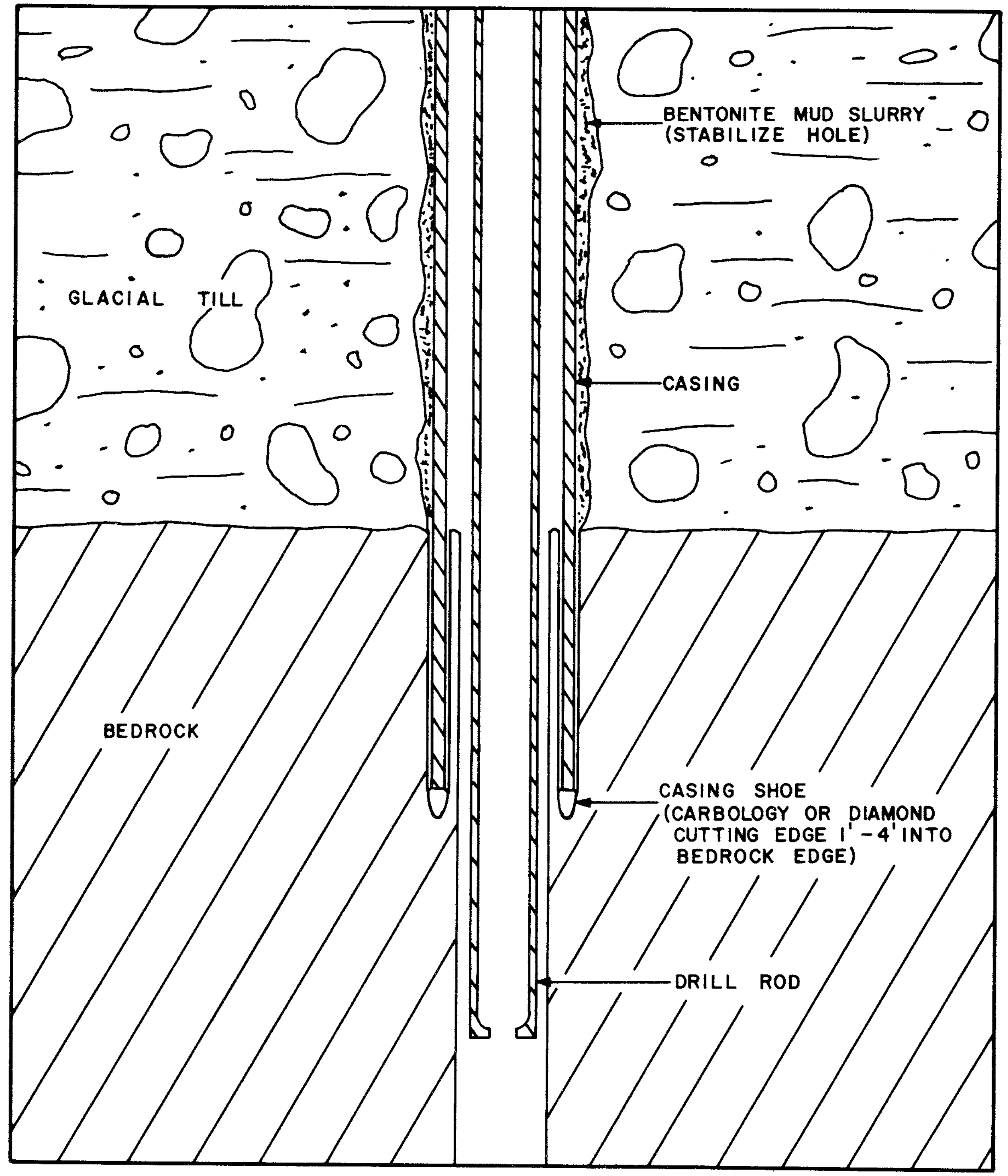
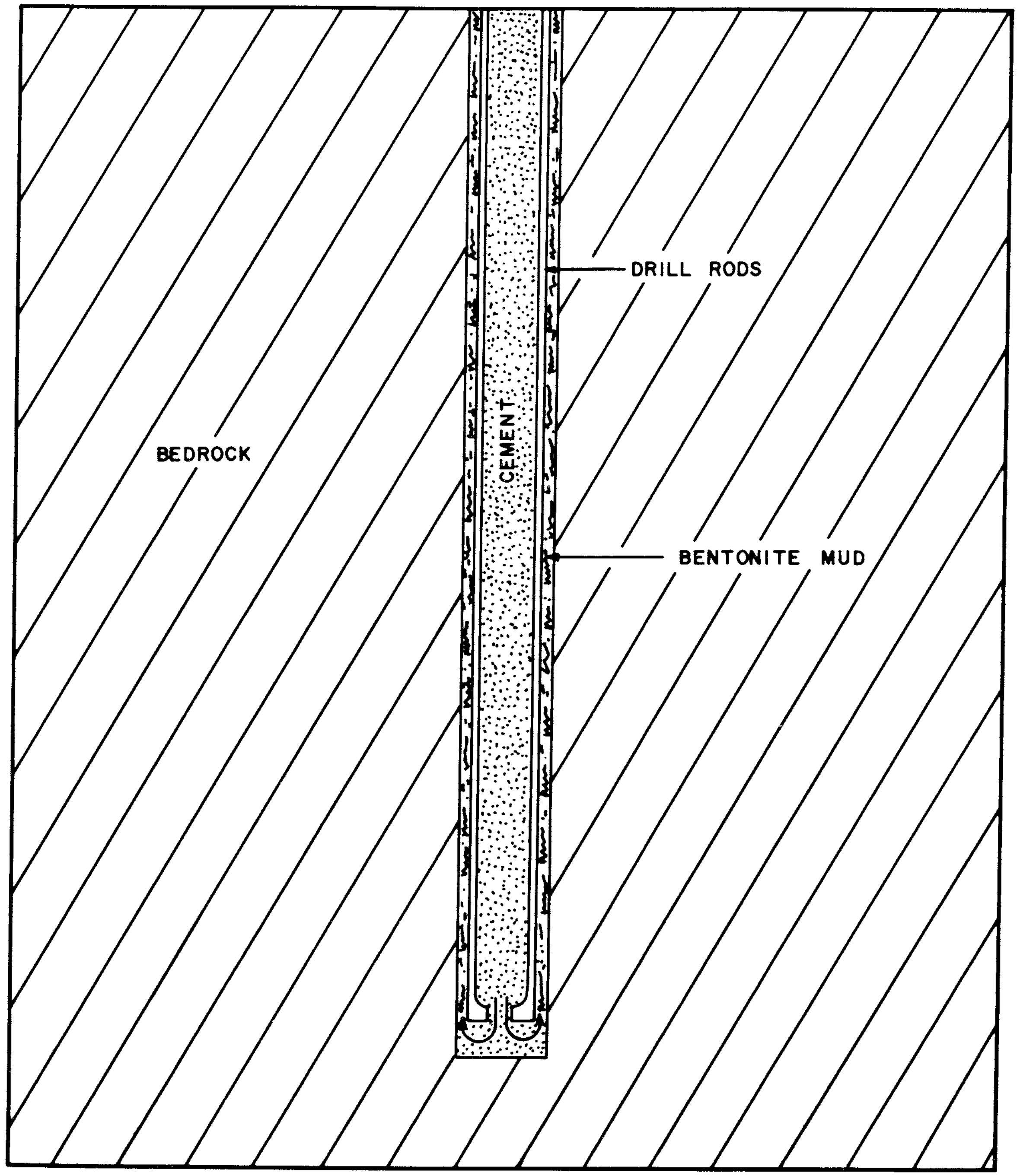


FIGURE 9. AN ILLUSTRATION OF THE METHOD USED TO CEMENT THE HOLE TO SEAL IT FOR ABANDONMENT.



geological formations is altered. This is an inevitable consequence of drilling. It occurs with all drilling, but the degree of disruption varies with the type of geological formations encountered.

In order to minimize the probability of vertical contamination as drilling is in process, the driller can place pipe in the hole to line (case) it. Then, upon completion and abandonment of the hole, it can be sealed with cement to prevent escape of gases, liquids and solids to the surface.

Figures 6 through 9 illustrate a typical method to drill and cement an uranium exploration test hole. Rocky Mountain Energy Company has developed and followed this procedure in Minnesota under state supervision.

Figure 7 indicates the initial drilling in the glacial till. A tri-cone rock bit is used to cut through the till and a bentonite mud slurry is injected around the drill to stabilize the hole. This system will be used until the underlying precambrian bedrock is encountered. Once the driller has encountered the precambrian bedrock, a casing of pipe will be set in the hole. This will provide a good seal between the bedrock-glacial till interface. It also will prevent sand and gravel from the glacial till entering the drill hole and producing bending and excessive wear on the drill rods (Figure 8).

Upon completion of hole and collection of in hole data as well as sampling of the cuttings, the hole will be abandoned. In order to seal the hole and restore the vertical and lateral integrity, cement will be pumped into the hole until it is filled to the bedrock-glacial till interface. The drill rods are then removed from the hole and the casing is freed from the bedrock. Cement is then pumped in again until it is sealed at the surface (Figure 9). The cementing and sealing process may take 8 to 20 hours.

4. Health Impacts of Uranium Exploration

There are two populations of concern when considering the health effects of uranium exploration; occupational workers and the general public. In relation to uranium exploration, the potential and actual release of radon gas from an open drill hole and its health impact is the major public concern. In the summer of 1980, the University of Wisconsin - extension service, through the Ecological and Natural History Survey, prepared a report on the safety issues associated with uranium exploration for the Wisconsin Legislative Mining Committee and Sub-committee on uranium exploration safety (47).

The report identified three ares of potential radiological exposure to the general public; groundwater contamination, mud pit contamination and radon release to the atmosphere. The conclusions reached were based on the development of a "worst case exposure" model for exploration drilling. That is, in calculating the potential exposures to drilling personnel, exploration geologists and the general public, it was assumed that the exploratory hole would encounter a "high-grade" uranium deposit (the richest uranium ore zone currently mined). In addition to this "worst case" assumption, a range of potential exposures was estimated on the basis of a typical uranium deposit likely to be encountered in geologic settings similar to northern Wisconsin.

The uranium concentration for the "worst case" and "typical deposits" are 7.7% and 0.3% U_3O_8, respectively. The high value is based on known values identified in the Cluff lake orebodies in Saskatchewan, Canada, while the typical values are based on orebodies in Washington and Colorado. The report also calculated the potential for radiation hazard from the three principal methods of uranium drilling; diamond-core, rotary-mud and rotary-air drilling. The report compared the exposures calculated for uranium exploration with human exposure from other radiation sources including natural background radiation levels. It also compared the exposure from uranium exploration to existing federal exposure standards.

a. Exploration Worker

Presently, the annual natural background general population radiological exposure is about 105 mrem. The standard for general public exposure is presently 500 mrem/year excluding the background exposure. Potential radiation impact of exploration workers per drill hole is significantly below the 500 mrem per year occupational standard based on the data in table 5.

If a driller used the diamond-coring drill method, he/she would have to work at about 1,111 individual drill holes per year to reach the permitted annual exposure of 500 mrems. Each hole would have to encounter a uranium ore body equal to seven percent U_3O_8 as used in the worst case exposure. If "typical deposits" of 0.3 percent uranium content was encountered, a driller would have to work on about 50,000 exploration holes per year.

The rotary-air drilling method, under the model posed here, would result in the greatest radiological exposure to the driller. A driller could only work at about 37 individual drill holes for "high-grade" deposits and about 1,388 individual exploration holes for "typical" deposits before approaching the annual radiological exposure limit.

The driller would have higher radiological exposure than the geologist with the rotary-air drill method while diamond-coring and rotary-mud drilling methods would result in greater radiological exposure to the geologist on site. This is primarily due to the subsequent storage and analysis of the uranium-bearing material by the geologist. For example, a geologist would have to work on about 80 individual drill holes with the diamond-core drill method to reach the annual radiological exposure of 500 mrems for the "high-grade" deposit and work at about 4,166 individual holes with a "typical" deposit. Thus, with the proper monitoring by exposure badges and rotation of personnel, the risk of potential radiation hazard to the uranium exploration drilling crews and geologists is minimized and should not pose a significant health risk. The following except from the Wisconsin report explains this conclusion (47).

"Radon emanation from boreholes produced by rotary-mud and diamond-core drilling is considered insignificant because of the slow rate of radon emanation and the typical coating of the borehole with mud. Radon gas is heavier than air and this further indicates radon release from a borehole is not significant. In addition, boreholes are not left open for any significant period of time in Wisconsin as per the Department of Natural Resources' requirements for temporary and permanent abandonment of drillholes."

Radon impact to the driller assumes dispersion of the air in and about the drill site as a result of normal air movement. Thus, the total radon impact results from radon brought to the surface over the length of time it takes the

drill bit to move through the uranium-bearing material. The air in the worker's breathing zone is assumed to have in any particular minute the radon that has been released by the drill bit in the previous minute's drilling. thus, the compressed air continuously replenishes the radon supply in the breathing zone, but the concentration remains constant as the previously released radon moves out of the breathing zone, is diluted by the atmosphere, and is dispersed away from the drill site and driller personnel.

Table 5. Potential Radiologic Exposure[1] of Exploration Workers Resulting from Uranium Exploration Drilling.

Drilling Method	Worker	"High-grade" Deposit	"Typical" Deposit
Diamond-coring	Driller	0.45	0.01
	Geologist	6.2	0.12
Rotary-mud	Driller	nil	nil
	Geologist	2.3	0.04
Rotary-air	Driller	13.4	0.36
	Geologist	2.3	0.04
	Radon[2] (driller only)	3.0	0.08

1 Units are mrem per drillhole
2 Units are working level-hours

"The radon is assumed to be in equilibrium with its daughter products for the purpose of calculating working levels (WL) of exposure of driller personnel. This assumption is plainly inaccurate and over-estimates the individual's exposure. However, the assumption greatly simplifies the calculation and is in keeping with the spirit of this memo to assume the "worst cause" situation where there is any questions of the amount of exposure."

"Radon exposure to the exploration geologist handling core and cuttings in the open air is insignificant, but radon levels in a storage/study facility may pose a potential hazard. this hazard is not significant if the facility is well-venelated. Measurements of radon in a core shack in British Columbia at an exploration site showed 0.005 WL, which is four times less than the Canadian federal limit of 0.02 WL for a member of the general public (British Columbia and Yukon Chamber of Mines, 1980). Ore grades associated with this exploration site are lower than those modeled for this memorandum, however. No further attempt is made here to evaluate the potential exposure to radon in a storage/study facility, but adequately ventilated facilities probably pose no hazard to workers."

b. General Public

Since the general public will normally not be present during the actual drilling operations and are not normally involved in the handling and analysis of uranium bearing samples, the potential for radiological exposure is associated with the mud pit, radon in the atmosphere and potential groundwater contamination. The exposure to the general public from the mud pits is not considered significant. For example, in the "worst case" situation, radiological exposure from the mud pit is 0.3 mrem/hour. This means an individual would have to be within 1 meter (about 3 feet) of the mud pit for over 1,500 hours (about 9 weeks) to absorb a radiological dose approaching the permitted 500 mrems/year annual limit.

Radon release from the drill hole is a source of atmospheric exposure to the general public, but it is not a significant increase above background radon levels as it mixes with the atmosphere and moves away from the drilling site (47).

"Since the borehole is not left open for any significant period of time, the general public's exposure potential to randon results from the drilling process itself. Radon would appear to be a problem of concern only for rotary-air holes, since the opportunity for radon release into the atmosphere is significant in any way only for this type of drillhole. Certainly, some aeration of radon entrapped in mud and water associated with coring or rotary-mud drilling would occur at the point of slurry release into the mudpit; however, this aeration would not be 100 percent and modeling the assumed 100 percent effective release of radon from rotary-air drilling appears to be the "worst case". Based on the preceding, the general public's exposure to radon would be equal to the toal release of radon, diluted by the compressed air, and further diluted and dispersed in the open air about the drill site."

"Extreme diurnal, seasonal, and other temperature variations associated with climatic and meteorologic conditions greatly complicate any straight-forward calculation of radon exposure downwind from a drilling area. Several studies of radon dispersion demonstrate that radon concentrations and working level measurements decrease with increasing distance from this source (as well as being a function of climatic and meteorologic factors). For example, data on radon concentration in the vicinity of an uranium mill in New Mexico shows a ten-fold decrease in air radon cocentration at distances of 500 to 3,000 meters from a tailings pile. Because radon released from a drillhole is much less to begin with, the phenomenon of dilution and dispersion with distance indicates that general public exposure to radon as a consequence of uranium exploration drilling in remote areas is not a significant problem."

C. Groundwater Contamination

The potential for ground water contamination was also assessed in the Wisconsin report (47).

"Concern with the contamination of groundwater aquifers centers around the introduction of natural uranium into aquifers as a result of drilling into uranium-bearing material and subsequently "losing" drilling fluid into an aquifer. Other concerns that have been expressed, specifically interaquifer communication along the borehole, does not appear to be a significant concern because (1) State of Wisconsin abandonment procedures are designed to eliminate this possiblity, and (2) if the abandoned hole does lose its integrity (cement deteriorates permitting movement of water along the borehole), the amount of uranium introduced from one aquifer to another is within acceptable health standards (see calculations below).

Potential contamination of ground water via introduction of drilling fluid into an aquifer is unlikely, particularly in systems using a mud slurry to cool the drill bit and bring cuttings to the surface. The mud tends to seal the borehole and if fluid loss does nonetheless occur, the driller can detect this loss and drilling stops to permit additional steps, such as cementing the borehole and allowing cement to move a short distance into the porous rock or open fissure that was causing the drilling fluid loss. Besides the sealing of boreholes with mud or cement, exploration boreholes are generally cased (lined with metal pipe that just fits inside the hole) as the hole is drilled. Casing alone eliminates any significant possibility of drilling fluid loss, especially if the casing is adequately cemented into the bedrock below the overburden.

Assuming, however, that drilling fluid loss does occur, the following calculation estimates the impact on the groundwater. Given a nominal three inch diameter hole 300 meters in length and the mudpit dimensions noted previously, the volume of drilling fluid involved is approximately 30 cubic meters. Following the assumption that 3 ppm natural uranium is dissolvable into groundwater and 10 percent of the drilling fluid is lost (see Wells 1979; note that the solubility of uranium and percent-loss of drilling fluid are very high, "worst case" estimates), the following relationship derives:

1 g natural uranium = 6.77×10^5 pCi (Hersloff, 1980),
2×10^6 cm^3 of drilling fluid loss contains 6 g U-nat,

$$\frac{6 \text{ g U-nat}}{2 \times 10^6 \text{ cm}^3} \times 6.77 \times 10^5 \frac{\text{pCi}}{\text{g U-nat}} = \frac{2 \text{ pCi}}{\text{cm}^3/}$$

The maximum permissible concentration of natural uranium (MPC_w) dissolved in water is 2×10^{-5} microcuries per cubic centimeter of 20 pCi/cm^3. This MPC_w also considers the chemical toxicity of the long-lived uranium nuclides (see Table 1, p.86 of NCRP Report No. 22 (1959), occupational exposurers allowed are divided by 10 to derive permissible non-occupational exposures).

The natural uranium introduced into an aquifer is less by a factor of at least 10 of the maximum permissible concentration. Therefore, the potential for groundwater contamination as a result of uranium exploration is not considered a significant problem, especially in view of the liberal assumptions made for uranium solubility and drilling fluid loss.

The respective radon concentration released by drilling into high-grade and typical deposits both exceed the maximum permissible concentrations of Rn-222 in air, according to NCRP Report No. 22 (1959, table 1). However, this table of MPC_a is for 40 hours per work-week or 168 hours per week of continuous exposure. The MPC's listed insure that maximum permissible body burdens for a particular radionuclide are not exceeded over a 50-year span of continuous exposure. The relatively instantaneous exposure of personnel on a drillrig cannot be compared to recommended levels of continuous exposure over 50-year time spans.

The use of MPC_w is reasonable, however, for natural uranium dissolved in groundwater as a result of drilling fluid loss into an aquifer. The MPC_w for soluble natural uranium used for comparative purposes in this memo is for continuous exposure over a normal 168 hour week for 50 years. The slow movement of groundwater suggests the dilution of uranium released into an aquifer may be so low as to permit the asssumption that the uranium concentration in the "contaminated" aquifer remains reasonably constant for a period of time that is commensurate with the assumptions in the MPC_w for soluble natural uranium."

B. Regulatory Framework In Wisconsin And Minnesota For Uranium Exploration

Based on this Wisconsin report, where the "worst case" conditions were employed to estimate worker and general public radiation exposure during uranium exploration drilling, the radiation hazard is shown to pose no significant health risk. However, this study is based on timely sealing of the drill hole after completion of data collection.

In order to insure adequate and timely sealing of the drill holes the State of Wisconsin regulates uranium along with other drilling activities. Their regulations require a driller to have a license to drill for metallic minerals and obtain a $5,000 bond for faithful performance and reclamation of drill sites. The driller must permanently seal the hole, usually with cement and the site is inspected by state personnel to insure compliance with license conditions (5).

In response to the public concern over uranium exploration in Minnesota, the Minnesota legislature passed a mineral exploration statute in 1980. It requires the licensing of mineral explorers, establishment of drill hole sealing and abandonment procedures and state inspection of drill sites. The major provisions provide for the following activities (3).

-Require that a mineral explorer secure a license from the Minnesota Health Department in accordance with existing regulations (anyone supervising drilling must first pass an examination on water well construction, unless the supervisor is a registered professional engineer in Minnesota or a certified professional geologist.)

-Require that 30 days prior to the start of drilling an explorer register with the Minnesota Department of Natural Resources.

-Require that 10 days prior to the start of drilling an exploration firm submit to the Minnesota Department of Natural Resources a county road map showing the location of each boring.

-Provide state and county officers and employees rights of access to drill sites for inspection and sampling of air and water.

-Require that the firm submit an abandonment report to the Minnesota Health Department and the Minnesota Department of Natural Resources within 30 days of temporary or permanent abandonment.

C. REGULATORY FRAMEWORK IN MICHIGAN FOR URANIUM EXPLORATION

1. Local Government

County, township and municipal governments can regulate mineral exploration and mining through the power of zoning established by the County Rural Zoning Enabling Act (P.A. 183 of 1943). Local governments can impose standards or criteria upon proposed exploration. Since the mineral owner has a strong property right to the recovery of minerals, local zoning ordinances cannot totally prohibit such activity.

The purpose of local zoning is to prevent creation of nuisance situations resulting from the presence of incompatible land uses. A zoning ordinance cannot, in general, prohibit any specific land use within a county or municipality unless it is shown that there is no location within the county where the use may be appropriately located.

The county zoning ordinances on mining currently in effect in Michigan typically set standards on noise, dust control, visual screening, operation and reclamation plans and protective fencing.

The fact that exploration could take place on state land would probably not eliminate local zoning control. The Michigan Supreme Court ruled that state lands are immune from the provisions of local zoning ordinances only when there is clear legislative intent that a state agency is to have "exclusive jurisdiction" over such an activity (Dearden v. City of Detroit, Michigan Supreme Court, August 1978). This does not appear to be the case with uranium mining on state land.

It is possible that a zoning ordinance could be written to drastically restrict or forbid uranium mining. In order to uphold the legality of such an ordinance, it must be shown that the ordinance is not unreasonable in its regulation of an activity and it is consistent with the protection of the public health, safety, or welfare of the citizens in its jurisdiction. Presently, most counties in Michigan do not have zoning ordinances for metallic mineral mining. The public reaction to proposed uranium mining may cause such ordinances to be promulgated.

2. State Government

Uranium exploration drilling on public and private land is subject to regulatory control in Michigan. Any drilling must be carred out in compliance with the Mineral Wells Act (P.A. 315 of 1969) which is administered by the Department of Natural Resources, Geological Survey Division.

Under the provisions of this statute a mineral well includes four types of wells; disposal, storage, brine and test wells. Uranium exploration would be considered either a general test well or a geophysical test well since it is drilled to determine the physical presence of uranium bearing orebodies. Although all four types of mineral wells must meet specific requirements and a permit issued before the actual drilling and use of the well, only the statutory standards and rules applicable to uranium exploration drilling will be discussed here.

The supervisor of mineral wells (state geologist) must approve and issue a permit before an operator can drill a test well. The operator is required to submit the following information in a written application.

1. A description of the exact location of the proposed test well on a map or plat.

2. The map or plat of the well area should indicate the relationship of the proposed well to lakes, streams, swamps, drainageways, other wells, buildings, streets, highways, pipelines, power and other utility lines, railroads and other features within 300 feet of it.

3. A detailed description ofthe proposed well construction.

4. A detailed description of the proposed drilling procedure.

5. A detailed description of the proposed plugging and abandonment procedure.

6. A description of the approximate depth of the hole.

7. Proof of acquisition of a surety or security bond.

8. A stake or marker is set at the proposed well site to mark the exact location in the field.

9. An organization report is provided if required.

This information must be provided for each proposed well site. However, the statute allows for the granting of blanket permits in a limited geographic area. A blanket permit may be issued for test well drilling and geophysical test holes. If it is issued for test well drilling, the operator is limited to drilling no more than 200 test wells in an area not to exceed nine square miles (1/4 of a township) as part of a geological test program. Under a geophysical test blanket permit an operator is also limited to no more than 200 holes except as authorized by the supervisor and the maximum area covered by each permit can be no larger than one county. The permit can restrict the area covered to less than one county for geologic reasons.

In order to obtain a blanket permit for a test well the driller must submit the following information in a written application.

1. A description of approximate number and locations of the proposed test wells on a map or plat.

2. A description of the proposed depth of the proposed wells.

3. A detailed description of the proposed well construction.

4. A detailed description of the proposed drilling procedure.

5. A detailed description of the proposed plugging and abandonment procedures.

6. Proof of acquisition of a surety or security bond.

Since a blanket permit for geophysical testing can cover a large geographic area (one county) than a blanket permit for test wells (1/4 of a township), the driller must provide, in addition to the information required for a blanket test permit, the following information in the written application.

1. The drilling plan must proposed alternative methods of plugging to cope with various soil and water conditions within the area to be covered by the permit.

2. The drilling plan shall specify criteria to be used in determining which plugging method is applicable.

3. The proposed drlling pattern of the wells.

Both types of blanket permits are valid for not more than one year and expire on December 31 of the year issued in.

Since a test well is defined in the statute to mean a well, core hole, core test, observation well or other well drilled from the surface to determine the presence of a mineral, mineral resource, ore or rock unit, an uranium exploration drilling program could be conducted under either an individual test well permit or under either of the blanket permits. In either case the supervisor, in reviewing the permit application, can deny a permit if the location and drilling of the well cannot be accomplished in a manner to prevent surface or underground waste.

The purpose of the act is to prevent surface or underground waste. The former is defined as damage to, injury to, or destruction of surface waters, soils, annual fish and aquatic life or surface property from unnecessary seepage or loss incidental to or resulting from the drilling and operating of brine, storage, disposal and test wells. Underground waste is defined as damage or injury to potable water, mineralized water or other subsurface resources. Thus, the statute allows the supervisor to include drilling and operating conditions in a permit to prevent surface and underground waste.

Based on a field review of the proposed test well locations and a review of the information in the written application, any or all of the following