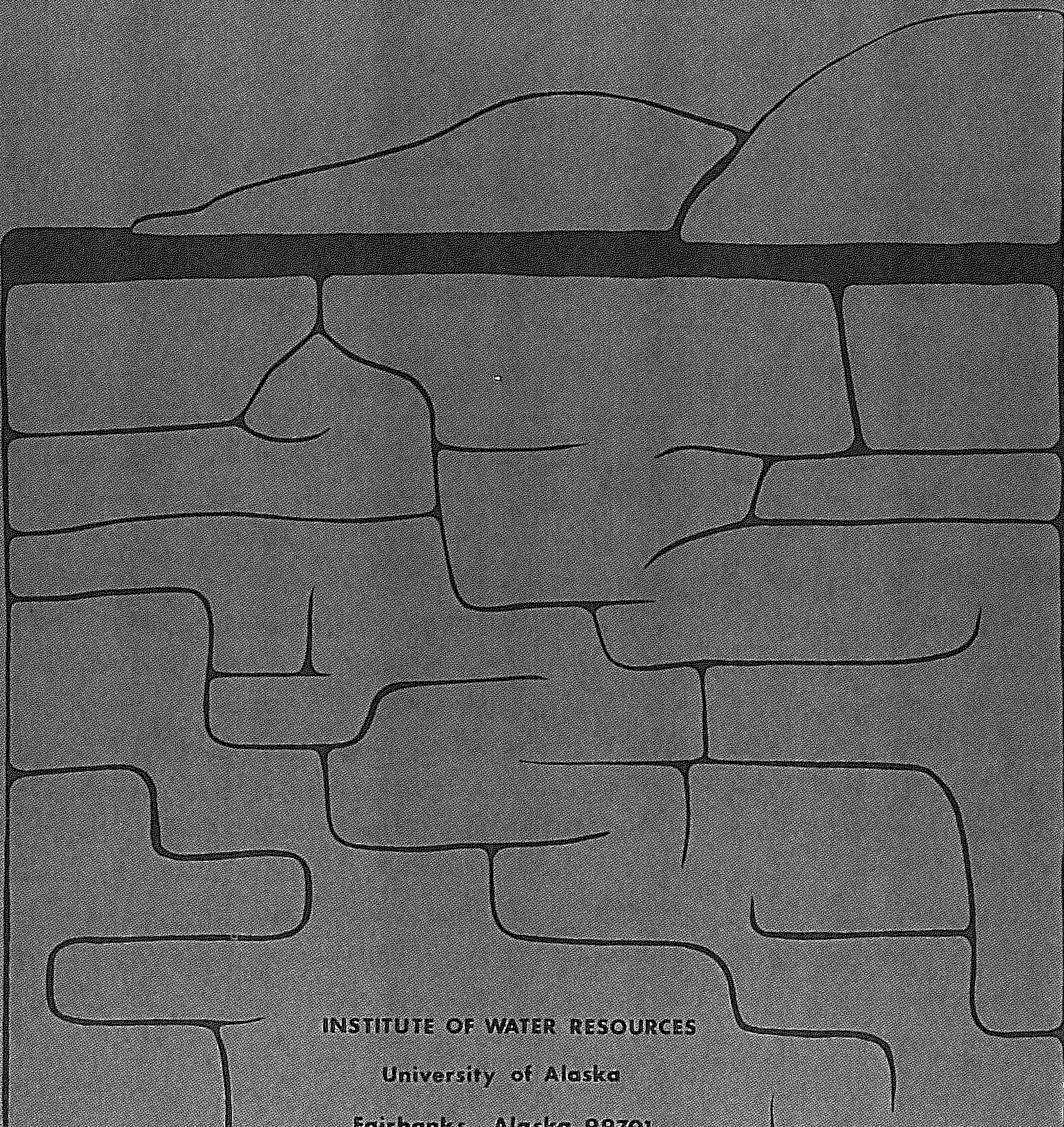
ENVIRONMENTAL PATH OF ARSENIC IN GROUNDWATER



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COMPLETION REPORT

OWRT Project No. A-050-ALAS

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Fairbanks, Alaska

Report No. IWR-77

October, 1976

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ACKNOWLEDGEMENTS

The work upon which this report is based was supported by funds provided by the United States Department of Interior, Office of Water Resources Research and Technology, as authorized by the Water Resources Research Act of 1964, Public Law 88-379, as amended. (Project A-050-ALAS)

INTRODUCTION

This is the final completion report for a project begun in July, 1974, for the purpose of determining the concentration of arsenic in the Pedro Dome-Cleary Summit area of the Fairbanks Mining District, Alaska. Because arsenic contamination of the waters of the area was detected during the first year, the study was extended for another year to examine for arsenic the waters of the Ester Dome area, a more populated part of the district.

This study was undertaken because it was known that arsenic as arsenopyrite and arseniferous pyrite accompanies the gold mineralization in the Fairbanks District. It was not known if such arsenic was liberated to the waters of the area by weathering processes. The Pedro Dome-Cleary Summit area was chosen for the initial study because arsenopyrite-bearing rocks are abundant and mining activities which might accelerate release of arsenic had long been carried out in the region. The area also had a few wells thus permitting a limited number of groundwater samples to be taken. The subsequently studied Ester Dome area permitted extensive sampling of the groundwater there.

From a health standpoint, 70 mg arsenic has proven to be toxic to humans, while arsenic in low concentrations appears to be a carcinogen. In view of these facts, the United States Public Health Service (USPHS) recommended guide limit for arsenic in potable waters is 10 parts per billion (ppb) with 50 ppb a level which, if exceeded, constitutes grounds for rejection of the water as a public water supply. Because of the rapid population growth in the Fairbanks area and the growing reliance upon domestic wells as a source of water by much of the population, it is important that the arsenic content of the surface and ground water be determined.

OBJECTIVES

1. To determine the arsenic content of surface and ground waters in parts of the Fairbanks District.

2. To determine if a relationship exists between the arsenic content of the rocks and soils of the area and that of the waters.
3. To determine if mining activities have influenced the arsenic content of the waters of the area.

RESEARCH RESULTS

Analytical Method Development

An analytical method using the atomic absorption spectrophotometer with graphite furnace and electrode-less discharge lamp was developed to assay for arsenic. This method gives results in good agreement with those from other laboratories using different analytical methods, e.g., neutron activation.

Geochemistry of Arsenic

Arsenic, particularly in groundwater, may be present in the trivalent state as the H_3AsO_3 complex or, possibly, as $H_2AsO_3^-$ at higher pH values (>9). Arsenic in a more oxidizing environment may occur as $H_2AsO_4^-$ or $HAsO_4^=$. All of these forms are mobile and will not be removed by the common household cation exchanger. It is possible that oxidation of arsenic to the $HAsO_4^=$ state coupled with coprecipitation with iron, which often accompanies the arsenic in the ground waters, may remove arsenic and thus may constitute a means for the removal of arsenic from domestic water supplies.

Arsenic in Water of Pedro Dome - Cleary Summit Area

In the Pedro Dome-Cleary Summit area, arsenic concentrations with a mean of 24 ppb and a range as high as 1200 ppb were found in stream waters. Stream sediments contained arsenic concentrations with a mean of 50 parts per million (ppm) and extreme values as high as 4000 ppm. The majority of samples showed arsenic concentrations in the groundwater to be less than 10 ppb. Three samples exceeding 50 ppb were encountered.

Streams known to have arsenopyrite in their drainages contain significantly more arsenic than those from non mineralized areas. This suggests using arsenic as an indicator element in hydrogeochemical prospecting to locate mineralized areas. Ground waters in arsenic-rich areas are also enriched in arsenic.

A positive correlation exists between the dissolved arsenic concentration of stream water and the arsenic content of suspended and bottom sediments. Variation in pH and temperature over the limited range encountered here has no clear-cut effect on the arsenic concentration of the stream waters.

Mill tailings discharged to streams by long-defunct gold-mining operations may have contributed to the now-observed arsenic content of the stream waters and sediments. Sluicing of gold-bearing placers done at present results in resuspension and partial dissolution of arsenic-enriched sediments. Arsenic is mobilized mainly as suspended load; when this load settles, the arsenic content of the stream water drops markedly.

Arsenic in Waters of Ester Dome Area

In the Ester Dome area significant arsenic contamination of domestic well waters was revealed. Concentrations as high as 10 ppm were encountered in two wells. Of perhaps 100 wells sampled to the present, between 1/3 and 1/2 have arsenic concentrations exceeding 50 ppb, a number of which contain an average of 400 ppb As. The arsenic-rich groundwater samples are all located on the mineralized belt which extends in a broad, southwest-trending arc from Pedro Dome-Cleary Summit to Ester Dome. Many groundwater samples with high concentrations of arsenic occur near known, arsenopyrite-bearing veins, some of which are currently being mined for their gold content. It is difficult to separate arsenic contamination as a result of mining an arsenic-rich area from that due to the arsenic-rich area itself. It seems, however, that arsenic contamination in the Ester Dome area stems from natural causes and mining has had little, if any, effect.

Very sharp arsenic concentration gradients exist in the ground water in the Ester Dome area. For example, one well may have less than 10 ppb arsenic, while another well only a few hundred feet away may contain 500 ppb arsenic. The reason for this distribution remains to be determined; peculiar hydrologic conditions may be responsible but control by arsenopyrite-bearing veins seems more likely.

The arsenic content of 30 soil and bedrock samples from the Ester Dome area ranged from 30 to 900 ppm and showed no apparent correlation with the arsenic content of the ground waters from the same areas.

When arsenic contamination of the wells in the Ester Dome area was revealed by this study in February, 1976, the Alaska State health authorities were informed. A cooperative study was begun which has now grown to include federal researchers from the U.S. Geological Survey, the Environmental Protection Agency and the Center for Disease Control. As a result of the study reported here, significant arsenic contamination of some of the waters of the Fairbanks District has been discovered. At least 30 families in the area have been shown to be intoxicated with arsenic. Subsequent studies to be carried out by the appropriate health agencies will determine the extent and seriousness of this intoxication.

DISSEMINATION OF RESEARCH RESULTS

As a result of this work, one M.S. thesis by Frederic H. Wilson has been completed and another by Dorothy Wilcox is in preparation. A paper entitled "Arsenic Content of Streams, Sediments and Groundwater of the Fairbanks Area, Alaska", coauthored by F. H. Wilson and D. B. Hawkins has been submitted to "Environmental Geology" for publication. An abstract of this paper is attached. An abstract of Dorothy Wilcox's thesis is also attached. Upon completion of her thesis, this work will be described in a paper for journal publication.

Copies of Wilson's thesis entitled "Arsenic and Water, Pedro Dome-Cleary Summit Area, Alaska" were distributed to the Alaska Department of Health and Social Services and to the Alaska Department of Environmental Conservation. Copies were also made available to Drs. Morse and Herrington of the Center for Disease Control. In addition, an informal exchange of information has been made with C. E. Tupper, Department of Public Health, Nova Scotia.

Several articles in the Fairbanks newspapers and interviews on radio and television with various investigators assured that the general public was aware of this work.

"Arsenic Content of Streams, Stream Sediments and Groundwater of the Fairbanks Area, Alaska"

Abstract: Arsenic concentrations with a mean of 24 ppb and ranging as high as 1200 ppb were found in stream waters, and arsenic concentrations with a mean of 50 ppm and extreme values around 4000 ppm were found in the stream sediments of the Pedro Dome-Cleary Summit area, Alaska. Twenty wells were sampled, three had arsenic concentrations equal to or slightly exceeding 50 ppb, the U.S.P.H.S. recommended limit for public water supplies. Samples were collected three times during the summer of 1974. The high levels of arsenic found are a result of arsenic enrichment in the rocks of the area. Placer and lode-gold mining may increase the arsenic concentration of waters by exposing arsenic-containing rocks to the waters of the area.

A precise and rapid method of analysis for arsenic, using atomic absorption spectrophotometry with graphite furnace was developed and used. [F.H. Wilson and D.B. Hawkins, submitted to Environmental Geology]

"Distribution and Geochemistry of Arsenic in the Groundwater of the Ester Dome Area, Alaska"

Abstract: The Ester Dome area is at the southern terminus of the mineralized belt extending from Coffee Dome and Cleary Summit south-

westward to Ester. Arsenic minerals associated with gold ores of the Fairbanks District include arsenopyrite, arseniferous pyrite and scorodite. Groundwater sampling in the Farmer's Loop, Goldstream Valley, Chena Ridge and Ester Dome areas in August, 1975, identified wells primarily in the Ester Dome area that contained high concentrations of arsenic. Eleven of the 46 wells originally sampled showed arsenic concentrations exceeding the U.S.P.H.S. limit of 50 ppb. Further sampling done in cooperation with the U.S. Geological Survey and the Alaska Department of Environmental Conservation in spring, 1976, added another 22 high-arsenic samples from the Ester Dome area. Arsenic concentrations in the well waters of this area range from less than 10 ppb to as high as 10,000 ppb. Thirty soil samples were analyzed for arsenic and showed concentrations ranging from 30 to 900 ppm. No correlation is apparent between the arsenic in these samples and that of the waters. Although the arsenic in the groundwater stems from leaching of arsenopyrite and scorodite, it is not clear whether the sharp concentration gradients observed in the ground water are due to hydrologic conditions or underlying bedrock. Geophysical logging of some high-arsenic wells was inconclusive.

The toxicity of arsenic is well known. Health problems in Taiwan and Nova Scotia are associated with ingestion of water containing similar concentrations of arsenic to those in the wells from Ester Dome. The Environmental Protection Agency and the Center for Disease Control are currently studying residents of the area to see if they face danger from arsenosis. The results of this study should be available by 1977. [Dorothy Wilcox. Tentative M.S. Abstract.]

TRAINING

Two M.S. theses, previously discussed, resulted from this study. In addition, as part of the National Science Foundations Student Oriented Programs, a proposal is being submitted by an interdisciplinary group of undergraduate students from the University of Alaska to study various problems on arsenic geochemistry as revealed by this study.

COLLABORATION

Gordon Nelson, U.S. Geological Survey, Water Resources Division, Fairbanks Office, closely collaborated on the Ester Dome part of this study. Indeed, because of instrumental difficulties encountered in our laboratory, the initial analyses revealing arsenic contamination in the Ester Dome area were done by the U.S.G.S. Laboratory at Salt Lake City, Utah.

Work in the Pedro Dome-Cleary Summit area was initiated by funds from the Alaska Department of Health and Social Services provided by Dr. Mickey Eisenberg, then state epidemiologist. This department, through Dr. John Middaugh, present state epidemiologist maintains an active interest in this work and subsequent collaborative studies are planned.

William Morgan of the Alaska Department of Environmental Conservation collaborated on the Ester Dome area study. His agency has the responsibility for sampling and analyzing waters for domestic use. This work is continuing in the Ester Dome area.

Various members of the staff from the Planning Office of the Fairbanks North Star Borough collaborated in the latter parts of the Ester Dome study.

Finally, Dorothy Wilcox and I have assisted Dr. Gunther Craun, Environmental Protection Agency, Cincinnati, Ohio; and Drs. Malcolm Herrington and Dale Morse of the Center for Disease Control, Atlanta, Georgia, in planning their subsequent studies of health aspects of the arsenic contamination in the Ester Dome area.