Ohio's Fractured Environment: Introduction to *The Ohio Journal of Science's* Special Issue on Fractures in Ohio's Glacial Tills[1]

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Abstract. This paper describes the importance of subsurface fractures in Ohio glacial tills and provides a historical perspective on fracture research and educational efforts in Ohio. It also serves as an introduction to and overview of this special issue of *The Ohio Journal of Science.*

Dedication. This special issue is dedicated to the memories of George W. White and Richard P. Goldthwait. They provided the foundation and inspiration for the work that is presented here. And the work continues.

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INTRODUCTION

For years, glacial tills and other clay-rich sediments were considered to be impermeable, and thus to represent excellent media in which to bury and confine solid and industrial wastes. This was the widespread perception, even though much earlier, some geological and soil scientists had recognized the presence of small cracks or joints, and other tiny pathways, in these deposits. It is only recently that the significance of these small but critical pathways for ground water flow and contaminant transport has been recognized. This recognition has led to a major effort to locate and describe such hidden fractures, to assess their environmental importance, and to share this information with those concerned with such problems. This effort led to the publication of the papers in this special issue on fractured till in *The Ohio Journal of Science.*

Historical Perspective

A review of Ohio's geological and soils literature indicates that the first descriptions of "joints" in clay tills were made in 1880 by M. C. Read, a lawyer-naturalist-geologist from Hudson, OH (White 1982). The first collective documentation of fractures was made by Ohio's soil scientists who often noted them as part of their soils mapping process. Fractures were a formal topic in 1971 in a multidisciplinary Till Symposium held at The Ohio State University (Goldthwait 1971). George White, a respected glacial geologist and former State Geologist of Ohio, repeatedly wrote of fractures. His summary of their persistence and critical importance in contaminant transport is recorded in *Glacial Geology of Northeastern Ohio* (1982), and is the most important Ohio publication from that decade that discusses fractures in till.

Importance of Fractures

Ohio's soil surveys, county by county inventories of Ohio's surficial cover, indicate that fractures have been identified and described in the majority of glaciated counties in the state. In addition, fractures have been documented by the Ohio Department of Natural Resources (ODNR) Divisions of Geological Survey, Water, and Soil and Water Conservation; US Geological Survey, Department of Agriculture-Agricultural Research Service (USDA-ARS), and Natural Resources Conservation Service (USDA-NRCS); Ohio Environmental Protection Agency (OEPA); numerous college and university researchers; and private individuals. These observations are detailed in several of the papers presented in this special issue (Brockman and Szabo 2000; Tornes and others 2000; Fausey and others 2000).

Water in fine-grained glacial and alluvial materials travels down from the surface to underlying ground water aquifers principally through fractures (termed secondary porosity) and not by flow between the grains (termed primary porosity). Because the rates of drainage are relatively rapid, reaching as much as two to three orders of magnitude faster than laboratory hydraulic conductivity measurements would indicate (Haefner 2000), there is little time for water to interact with the materials it is passing through. While this is not necessarily a problem when considering water movement, it is a critical issue when recognizing the kinds of contaminants that can move with that water. Whether it be regional non-point source contaminants like agricultural fertilizers and pesticides, urban lawn and garden chemicals, or highway de-icing road salts, these materials are carried into the underlying ground water where they may become part of the source water for private and public wells. Ohio's ground water is tapped by over 800,000 private water wells (ODNR 1998) and approximately 40% of all the public water supplies in the state (OEPA 1987). In addition, contaminants from point-source locations also contribute to ground water pollution. These point sources can be as varied as on-site septic systems, underground tanks at corner gas stations, or historic abandoned or grandfathered landfills.

The information learned about fractures in Ohio tills can be directly transferred to other glaciated regions of the world. It is also applicable to other fractured unlithified materials including lacustrine and marine sediments, and, to a lesser extent, fractured rock environments.

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Overview of this Special Issue of *The Ohio Journal of Science*

This special issue is composed of eight separate research papers covering educational outreach, basic sciences, and selected assessment methodologies that describe the current state of knowledge about fractures in Ohio's glacial settings. The authors of these papers represent a portion of a team of researchers (the Ohio Fracture Flow Working Group) from a variety of disciplines, including soil science, geology, engineering, horticulture, law, public health, planning, and education—professionals serving government agencies, public universities, and the private sector. More papers are planned for later publication in *The Ohio Journal of Science*. These papers will include additional selected methodologies, case studies, applications, and legal and planning analyses.

Papers in this special issue discuss the mechanisms of fracture formation (Brockman and Szabo 2000) and the relationship between soil characteristics and the probability of the presence of fractures (Tornes and others 2000). Ohio scientists are beginning to build a database of known fracture locations and conditions under which they develop so that it may be possible to predict fractures (Fractures in Ohio's Pleistocene Unconsolidated Deposits and Soils, 2000). Tornes and others (2000) describe how secondary fracture porosity contributes to overall hydraulic conductivity and varies depending on the relative amounts of clay and silt in the matrix materials (for example, where a given material falls on the USDA textural triangle). This is a powerful tool in defining conditions where secondary porosity/fracture flow should be anticipated, planned for, and investigated in any site assessment.

Christy and Weatherington-Rice (2000) describe a field workshop on fractured till and provide a more detailed history of the Ohio Fracture Flow Working Group. Fausey and others (2000) present the till properties at the Field Workshop Site, quantifying the differences in hydraulic conductivity and in physical and chemical properties between fracture-affected zones and the till matrix. The influence of fractures on the geotechnical engineering properties of glacial till is described in Allred (2000). The role of biological systems including plants, earthworms, and microorganisms in fractures is reviewed by McMahon and Christy (2000).

Two methodology papers are included in this special issue. Haefner (2000) provides an extensive survey of characterization methods for fractured glacial tills. Christy and others (2000) describe the design and construction of deep soils/geologic test pits for environmental site investigations.

Educational and Outreach Efforts

Beginning in 1993, a team of scientists came together under the umbrella of The Ohio Academy of Science (OAS) to discuss the issue of fracture flow and began an educational awareness campaign for professionals in the field and the general public. To that end, the OAS hosted a formal one-day symposium at Toledo in 1994 as part of the Annual Meeting. They also joined with the Association of Ohio Pedologists, Bowser-Morner Inc., and Bennett & Williams Environmental Consultants Inc., to host a field day at The Ohio State University's Molly Caren Agricultural Center in Madison County in August 1997 (Christy and Weatherington-Rice 2000). In addition, the issues of fracture flow have been discussed either at the business meeting or in paper presentations at each annual OAS Earth and Space Sciences meeting since 1993. The afternoon session of the 1998 meeting dealt extensively with the issue of glacial till geology.

Word of the team's research efforts in Ohio has spread internationally. The organizers of this special journal issue were invited to present a paper and a poster at the Mass Transport in Fractured Aquifers and Aquitards conference held in Copenhagen, Denmark, in May 1998.

A number of related projects will follow this special issue. More technical papers are currently being written by the Working Group for later publication. Other researchers are encouraged to submit their own papers on fracture flow to *The Ohio Journal of Science* and to the Ohio Fracture Flow Working Group for consideration for publication. In addition, the Working Group has established a web-based fracture data and information site (http://www.oardc.ohio-state.edu/fractures). The Water Management Association of Ohio (WMAO) has requested that the team hold a state-wide workshop in May 2000. There are also plans to construct a permanent soils/geology pit at the Gwynne Conservation Area of The Ohio State University's Molly Caren Agricultural Center to be available for learners from grade school, high school, college, and beyond.

Why Publish in *The Ohio Journal of Science*?

As the organizers worked through the varied issues related to fractures in fine-grained materials, it became readily apparent that there was a need to publish these findings in a single multidisciplinary journal. The traditional approach would have been for varied specialists to write papers for their own respective technical journals. In following the traditional approach, the strength of the group's combined knowledge would have been diminished. In addition, those who are most affected by contaminant transport through fractures, such as professionals in the fields of public health, natural resources, and regional land-use planning, might never see the information in those technical journals or link the importance of this research to their daily considerations. The Working Group decided that it was important to tell a "whole story for Ohio" in a manner that could be read by professionals here in Ohio and in other states and countries. Since the OAS has supported the Working Group's efforts for the last seven years, it is fitting that the results of this ongoing research be published here in *The Ohio Journal of Science*.

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