A bibliography of various geological and geophysical data sources was compiled as part of an overall effort to evaluate the status of research on the Great Lakes. We hope that such a summary will be a catalyst for additional work and be an aid in planning future work. Our presentation has two forms: maps showing the locations of the different data types and a bibliography which lists the references from the maps and additional relevant papers. The charts shown in this map summarize the data sources for Lake Michigan.

The physical task of compiling the vast amount of published papers and unpublished reports and theses necessarily limited our objectives: we include only studies dealing with the lake proper. No attempt was made to summarize the investigations over surrounding land areas or to list the innumerable beach studies conducted by investigators at various universities and State and Federal agencies. Nor did we include studies dealing only with the water column (limnological work).

A few comments should be made concerning our guidelines in compiling the bibliography. We included all references we found (excepting beach and limnological studies). We included abstracts only when no follow-up paper occurred; we included both theses and resulting publications. Publically accessible data which have not been open-filed or published are referenced as a personal communication which shows the date when we obtained the data and the location where the data are available for public inspection.

We divided the bibliography into basic topics: seismic reflection surveys, magnetic surveys, gravity surveys and sampling surveys. Some references are listed under more than one section. We also created a "General" reference section which lists those papers that are relevant but do not fit the above categories. Finally, we found the following sources extremely useful in our compilation.

1. Existing bibliographic publications:

Publication	Source
Great Lakes Research Checklist	Great Lakes Commission 2200 Bonisteil Blvd. Ann Arbor, MI. 48105
Publication of the International Association of Great Lakes Research	Dr. Merv D. Palmer IAGLR Treasurer c/o Water Res. Br. Ontario Ministry of the Envir. 135 St. Clair Ave, West Toronto, Ontario M4V 1P5 Canada
Bibliography of Current Research on Geology of the Lake Superior Region	Dr. M.M. Kehlenbeck Dept. of Geology Lakehead University Thunder Bay, Ontario P7B 5E1 Canada
Bibliography of Published Geologic Papers and Unpublished Theses of the Great Lakes and their drainage basins, 1950 through 1958	Zumberge, J.H., 1960, in Proceedings 3rd Conference on Great Lakes Research, Ann Arbor, Michigan, 1960 University of Michigan Publication #4, p.51-59.
Microfilm of Theses; Great Lakes Research Checklist	University Microfilms P.O. Box 1346 Ann Arbor, MI. 48106

2. Journals and Proceedings:

Journals of Great Lakes Research (Volume 1, published in 1975).

Proceedings of the Conference on Great Lakes Research (21 conferences held through 1978). Proceedings of Annual Meeting of the Institute on Lake Superior Geology (24 meetings held through 1978).

3. Navigation and bathymetry chart indices:

Nautical Chart Catalog 4 (U.S. Great Lakes and adjacent waterways)	Available from: NOAA, Distribution Division (944) National Ocean Survey Riverdale, MD. 20840
Information Bulletin 1 (Canadian Nautical Charts, Great Lakes and adjacent waterways)	Available from: Canadian Hydrographic Service Distribution Office Dept. of the Environment 1675 Russell Rd.,P.O. Box 8080 Ottawa, Ontario K1G 3H6 Canada

4. Principal Organizationsinvolved in Great Lakes Geological Studies:

Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL. 60439	Department of the Army Coastal Engineering Research Center Kingman Building Fort Belvoir,VA. 22060
Canada Centre for Inland waters 867 Lakeshore Rd., P.O. Box 5050 Burlington, Ontario L7R 4A6	Great Lakes Research Division University of Michigan Ann Arbor, MI. 48106

We have several explanatory comments for the charts. The data have been grouped together according to the type of survey: seismic reflection, gravity, magnetic or sampling. For sampling where the data are dense, we further divided the maps into a "Generalized" and a "Specialized" map. The "Generalized Sampling Surveys map" shows those studies that either sampled throughout the lake or dealt with the geological history of the lake. The "Specialized Sampling Surveys" map shows studies either restricted geographically to one part of the lake or highly specialized in analysis (e.g. X-ray stratigraphy, element analysis or manganese nodule occurrence). The large-scale seismic maps are compiled on standard polyconic projections which overlay either National Ocean Survey charts or Canadian Hydrographic Service bathymetry maps. The small scale maps are half-scale reductions of the same projection.

In some cases, more than one author has published studies of parts or all of the same survey. To accomodate this on the legends, we listed the earliest reference which describes the total survey first and subsequent references alphabetically. We then organized the legends chronologically by the earliest reference. In papers dealing with sampling, it was not always clear whether some samples came from the same survey, or from identical locations in later surveys. These have been grouped together. The legends do not reference theses unless follow-up papers were not published. For heavy density sampling surveys, we show the study area as a shaded portion on the chart.

We caution the reader that the charts we show are not scrupulously accurate. The data were plotted as carefully as possible, but location errors arising from enlarging small scale maps in journals are inevitably present. Where we could obtain large scale maps from authors, these were utilized and referenced as a personal communication.

We feel that we have listed the bulk of the publicly available data but we suspect other sources exist that were not readily available. For instance, it is apparent in some reports that additional cores and bottom samples (not shown on our charts) have been collected by the Great Lakes Research Division of the University of Michigan, Argonne National Laboratory, and Canada Centre for Inland Waters. Many M. S. theses are not always microfilmed at University Microfilms. Some published reports are now out of print. We hope that, if additional public data are available, investigators will let us know the purpose of the studies, type of data, location, publications, and availability of these data, so that we might update this summary. If any errors are found in our compilation we would like to know about these as well.

Lake Michigan Data Summary

The data summarized below correspond to each chart and are a first-order attempt to show the reader more specifically what types of data were collected in each survey. The references are grouped together as on the maps. An asterisk (*) before the reference indicates that it appears elsewhere in the same table with a different type of data. Where authors have used data from part of a survey, the full quantity is listed next to the first reference and the amount each author(s) used is listed in parentheses. For example, if a piston core survey shows the quantity 5 (3), that means five locations are shown on the map but this author (s) used only 3.

I Seismic Surveys

The seismic data collected in Lake Michigan have been mainly high resolution data (3.5 kHz or higher frequency sound source) with one 10 cu. in. air gun survey (Wold, 1978 and Wolosin, 1972). In order to show all of the track lines two charts have been used. The General Seismic Surveys Chart shows 11,500 km of reflection track lines and three short refraction lines (Woollard and Hanson, 1954). The Detailed High Resolution Seismic Surveys Chart shows 7,200 km of track lines including 210 km of towed electrical resistivity studies (Nebrija and others, 1978).

General Seismic Surveys-Chart Summary

Type of Data	Quantity-km	Reference
Refraction Lines (reversed)	3 profiles up to 3.5 km. long	Woollard and Hanson (1954)
Sparker	700	Hough (1967)
3.5 kHz	4000 (3000) (3000) (1800)	Moore (1970) Meyer (1969) Moore & Meyer (1969)
3.5 kHz and/or 7kHz	3000 (3000) (444) (1600) (420)	Lineback and others (1974) Lineback and others (1971) Lineback and others (1972) Lineback and Gross (1972)
10. cu.in.air gun	3700 (3700) (3700)	Wold (1978) Wolosin (1972)

Detailed High-Resolution Seismic Surveys-Chart Summary

Type of Data	Quantity-km	Reference
Side-scan sonar, 3.5 kHz and 25 kHz	416	Berkson and others (1975)
3.5 kHz and towed resistivity	210	Nebrija and others (1978)
14.25 kHz	5140	Wickham and others (1978)
Uniboom ** and 3.5 kHz	730	Williams (1978)

** Registered Trade-mark of EG&G, Inc.

Any trade names in this publication are used for descriptive purposes only and do not constitute endorsement by the U.S. Geological Survey.

II. Magnetic Surveys

The Magnetic Surveys Chart includes 11,300 km of aeromagnetic data collected with a digital recording proton precession magnetometer system. In addition 15 core sites are shown which were used for paleomagnetic studies. Two additional cores were collected for paleomagnetic work (Keen & others, 1975) but their locations are not known.

Magnetic Surveys - Chart Summary

Type of Data	Quantity	Reference
Aeromagnetic	11,300 km (11300) (1200)	O'Hara and Hinze (1972)
Paleomagnetic Cores	9	Vitorello (1975) Vitorello & Van Der Voo (1977)
Paleomagnetic Cores	6	Creer & others (1976)

III. Gravity Surveys

The Gravity Surveys Chart includes about 480 bottom-gravimeter stations and approximately 400 km of shipborne gravity data. The shipborne gravity data were averaged over approximately 4 km intervals resulting in the equivalent of about 1000 gravity stations. Overall, then, there are approximately 1500 gravity readings over Lake Michigan.

Gravity Surveys Chart-Summary

Type of Data	Quantity	Reference
Bottom Gravimeter	353	Wold (1969) O'Hara & others (1973)
Bottom Gravimeter Shipborne Gravity	33 ≈4000 km averaged over ≈ 4 km intervals	Iverson (1960)
Bottom Gravimeter shore	84 32	O'Hara (1971)
Bottom Gravimeter	11	Wold (1979)

IV. Sampling Surveys

Sampling stations were difficult to summerize because so many different investigations have been done for a wide variety of purposes. Frequently several papers written by different authors will report on complimentary aspects of samples taken from the same core or sampling station. Wherever it was obvious that this was done, only one sampling station is shown.

The Generalized Sampling Surveys Chart shows about 1900 sampling stations with a mixture of grab samples and cores up to 18 meters in length. The Specialized Sampling Surveys Chart shows about 2400 sampling stations with a mixture of surface samples, gravity cores up to 4 meters in length, and vibracores up to 8 meters in length in nearshore sand and gravel areas.

Generalized Sampling Surveys-Chart Summary

Type of Data	Quantity	Reference
Surface samples	80 (80) (28)	Lauff and others 1961 Henson & Herrington (1965)
Surface and core	56	Moore (1963)
Surface and core	103	Hough (1967)
Man dives	72 stations	Sommers (1968)
Surface samples & cores	700 (700) (200)	Moore (1970) Moore and Meyer (1969)
Sampling Stations	565 (565) (306 samples;379 cores) (184) (31) (15) (28) (49) (70) (15) (19) (56) (6) (42)	Gross (1970) Gross and others (1970) Kennedy and others (1971) Lineback and Gross (1972) Lineback and others (1970) Lineback and others (1971) Lineback and others (1972) Lineback and others (1974) Ruch and others (1970) Scheicher and Kuhn (1970) Shimp and others (1970) Shimp and others (1971)
Surface samples Cores	280 18 (including 5 up to 18m)	Wickham and others (1978)

Specialized Sampling Surveys Chart Summary

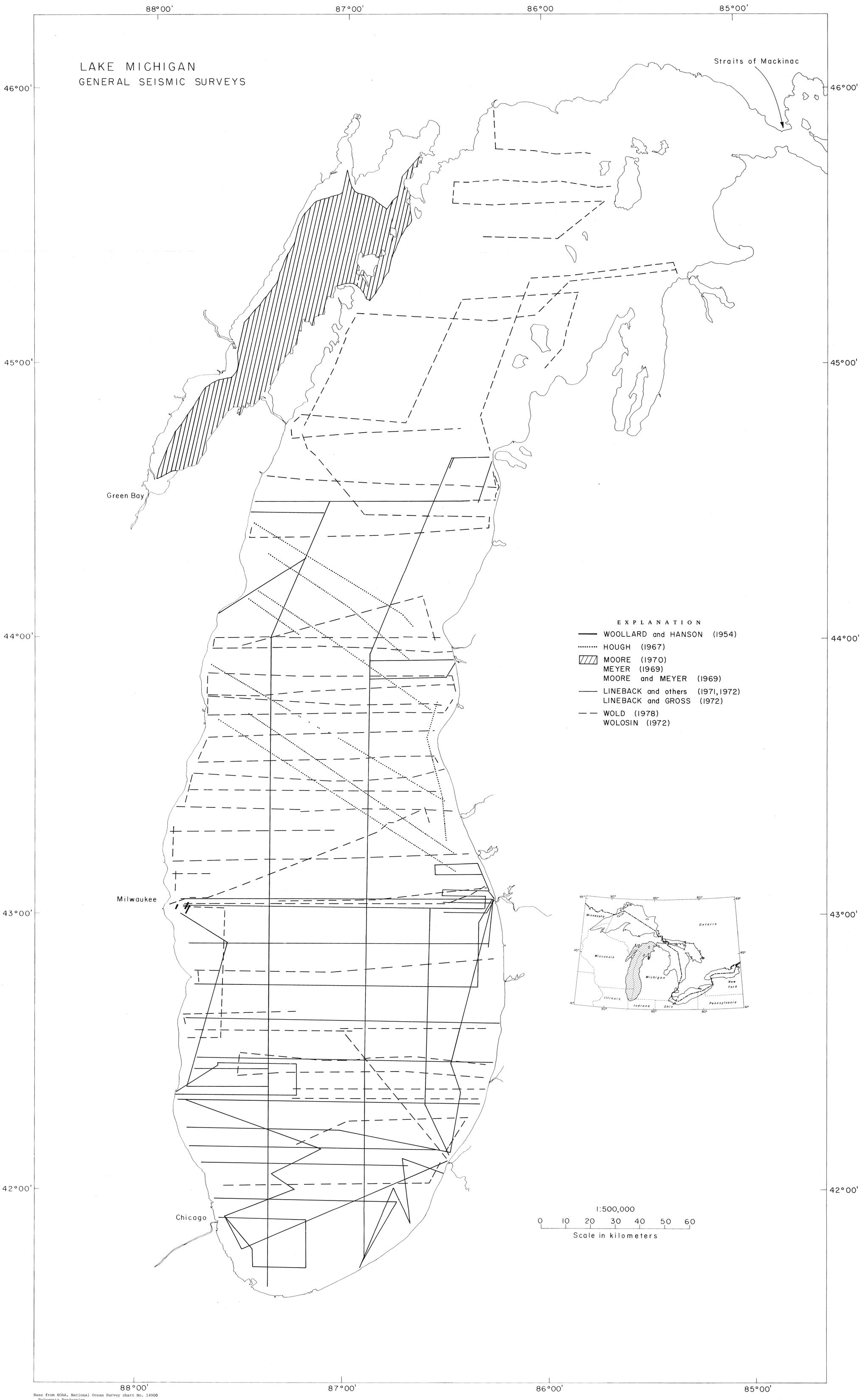
Type of Data	Quantity	Reference
Surface samples	450	Fisher (1954)
cores (up to 4m)	15	Hedrick & others (1966)
Surface Samples	875 (875) (524) (256)	Ayers (1967) Ayers & Hough (1964) Sommers & Josephson (1968)
Manned Submersible	14 dive sites	Great Lakes Research Div. (1968)
Surface samples & cores (up to 2m)	39	Callender (1969)
Surface samples & cores (up to 2m)	42	Rossmann & Callender (1968,1969)
Surface samples	6	Schelske & Roth (1973)
Surface samples	158	Seibel and others(1974) Rossmann (1975)
Surface samples Piston cores	71 16	Fitzbo and Hutchinson (1975)
Cores	53	Robbins & Edgington (1975)
Surface samples	270	Graf (1976)
Surface samples	61	Nebrija & others (1978)
Vibracores (up to 8m)	92	Williams (1978)

Review of Data

Lake Michigan overlies the western flank of the Michigan basin. In this area the basin is dipping to the east so that the thickness of the Paleozoic sediments varies from 500 meters along the western shore to more than 1600 meters along the eastern shore.

The southern half of Lake Michigan has been studied extensively by the Illinois State Geological Survey. The bulk of their studies and those conducted by others are devoted to understanding the glacial till and glaciolacustrine and lacustrine sediments. Very detailed studies have also been done of Green Bay, both high-resolution seismic and bottom sampling. The air gun work that has been done is limited in penetration to the surface of the underlying Paleozoic rocks. This interface apparently has a high acoustic impedance resulting in strong multiples and therefore limited acoustic penetration beneath this interface. The only deep seismic reflection data are the result of limited proprietary multichannel studies.

The gravity and magnetic data are adequate for regional studies of the underlying pre-Cambrian surface. No seismic-refraction data are available, except for three short lines off Milwaukee harbor; no deep seismic-reflection data are publicly available.



Base from NOAA, National Ocean Survey chart No. 14900
Polyconic Projection

LAKE MICHIGAN GEOLOGICAL AND GEOPHYSICAL DATA SOURCES

By
Richard J. Wold and Deborah R. Hutchinson

1979

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1979

For sale by Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202