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MICHIGAN GEOLOGICAL SURVEY

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Michigan Geological Survey Annual Report for 2015

The Michigan Geological Survey is pleased to present the 2015 Annual Report summarizing the activities and achievements to the State Geologist, Harold R. Fitch, per Senate Bill No. 507.

OVERVIEW:

The restructured Michigan Geological Survey (MGS) has been active at the Western Michigan University Geosciences Department for just over four years. The primary functions mandated for the survey by the October 11, 2011 legislation include: investigation of the state's geological resources, the collection and archival of geological samples, cores, cuttings, and the preservation of geological investigations. The purpose of the Michigan Geological Survey is to serve the state's people, industry, and governmental agencies (the clients).

The MGS activities continue to operate primarily on university funding and during the last year applications for additional grants have begun to be successful. The goal of the MGS is to be recognized as the "Go To" resource for geologic information in the state, both for the Lower Peninsula (LP) and the Upper Peninsula (UP). During 2015, the survey formalized the structure of nine resource centers. These resource centers are as follows: Michigan Geological Repository for Research and Education (MGRRE), Surface Mapping, Hydrogeology/Environmental geology, Energy, Economic Minerals, Geologic Hazards, Geological Information System (GIS)/Data Management, Remote Sensing, and Outreach (Attached). The centers provide scientific information to the public, to industry, and to the state legislature. Initially, the MGS has been incrementally supported by faculty and other contract and University staff resources. A fully functional Survey cannot occur until permanent, annually recurring appropriations and funding is provided to hire permanent professional staff that can integrate with the State departments and the Legislature to conduct needed and prioritized scientific geologic research.

The MGS Director, John A. Yellich, was requested to both introduce and to update interested stakeholders to the progress the restructured survey has made across the state. Included were meetings with directors in the governor's office, a community meeting with local elected officials, meetings with State Representative Aric Nesbit and State Senator Margaret O'Brien, and with local Township and County officials. The primary focus of many of these meetings was to present an overview of Michigan geology and the benefits that can accrue from a fully funded, functional geological survey supporting the evaluation of Michigan's energy, mineral, and water resources. The meetings not only presented Michigan geology and energy resources

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but highlighted the importance of the MGRRE facility to the State. Additional presentations, meetings and discussions were made with specific associations, committees and organizations that included: Michigan Manufacturers Association, Environmental and Mining Policy Committees; Michigan Groundwater Association; representatives of the Michigan Chamber of Commerce, Michigan Oil and Gas Association, Michigan Environmental Health Association, and MI CAMP professionals. The MGS presented talks on the geological concerns currently confronting the State of Michigan. These were associated with agriculture, industry, municipal and rural growth, water resources, resource development, aggregate industry, and data management.

The MGS proposed and successfully received a grant to present a demonstration platform for data quality management of geologic and other primary data that is comprised of an estimated million plus data points. These data are included in reports and other state controlled documents having geology, water quality and quantity that primarily exist in paper and other formats in state files. In their present form, these data cannot be used efficiently by the state or the public. At all meetings and presentations, the MGS underscored the benefit and the need for state funding if the MGS is to provide the science needed to address critical geological issues. MGS and Michigan Technological University (MTU) completed a Memorandum of Understanding (MoU). The MGS Director was invited to MTU in Houghton to meet with and discuss issues with Upper Peninsula stakeholders last October. This meeting resulted in a joint function for MGS and MTU, and was documented on local TV. First was the dedication of a high grade ore sample from the Eagle Mine, Marquette County which was presented to MTU. Second was a half day of discussions of Upper Peninsula (UP) issues with UP Stakeholders. Issues discussed were geologic mapping, airborne geophysical surveys, core repositories, and economic development in the UP supported by scientific research through the MGS and MTU. The stakeholders represented Upper Peninsula economic development staff, mining companies, USGS geologists and geophysicists, MDEQ geologists, and MTU faculty involved with geology, water, and natural resources in Michigan. The priorities recommended were state funding for core storage and coordinated data management to support economic development in the UP utilizing the scientists of MTU and MGS.

MGS attended a DEQ sponsored Water Collaboration workshop in Roscommon in October. Multiple topics were discussed by representatives from all the State Quality of Life Departments and universities. A specific notation by the water representatives from the Michigan DNR, referenced that any new water related operation needs factual geologic data to understand the chemical stability of that natural setting. In most cases factual geologic data is lacking. In order to make sound technical decisions, geologic data must be developed before a project can proceed. Again, long range planning with the MGS could develop the factual geologic data needed.

Michigan is the only Great Lakes state that has not committed to any annual funding for either statewide or specific, local geologic mapping. There are two mapping methods that can be independent but are more efficient if they are integrated, direct field mapping coupled with confirmation drill holes; and indirect airborne geophysics that can provide an expedited geologic and resource mapping program resulting in near term useable scientific data. This information would support future or continued natural resource management and economic

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development in the state. Funding to support the MGS mapping in Michigan was endorsed by Senator Thomas Casperson to the House Legislative Budget Committee last April.

MGS has presented significant documentation in support of completing high quality LiDAR (Light Detection and Ranging) mapping programs in most areas of the State. Such a program could expedite geologic mapping in many areas of the Lower Peninsula. LiDAR also supports all facets of Michigan's economic and business entities including agriculture, municipal development, drain commissioners, forestry, flood issues, aggregates and water resources. The LiDAR program, has finally garnered additional interest by many parties for implementation and completion as soon as practical using federal, state and local funding.

Quality airborne data collection associated with natural resources using airborne geophysics, the indirect measuring of earth's physical properties, has not been done in Michigan. MGS was introduced to a possible USGS demonstration program by Dr. Ben Drenth, USGS geophysicist, to test airborne geophysical methods, an aeromagnetic survey, to map buried geologic rock units and provinces. MGS had knowledge of this plan in the spring of 2015, and John Yellich personally discussed and lobbied on behalf of this proposed program with the director of the USGS, Dr. Suzette Kimball, and with other Washington USGS technical directors last June. MGS was notified in December that the USGS will fund such a test in Michigan in the amount of \$380,000. It is noteworthy that USGS can contract up to \$500,000, and expand this test if additional funds become available from industry or the state. The demonstration program will be done in the spring of 2016, and will be located in areas of the Upper Peninsula that have potential Precambrian geologic terranes buried under Paleozoic and glacial rock cover. Such a study can potentially lead to the discovery of new mineral deposits. A similar airborne aeromagnetic geophysical program was completed in Minnesota, and has resulted in multiple mineral discoveries, worth hundreds of millions of dollars in future economic value. The Minnesota discoveries were made in rocks similar to those in the Upper Peninsula of Michigan.

MGS has had meetings with representatives of the Michigan Oil and Gas Association (MOGA) concerning data sharing in areas of energy development, and is also working in concert with the Michigan DNR. MGS requested and MOGA is considering a voluntary program to provide previously un-released geophysical seismic data profiles to MGS to support the mapping of both the glacial geology, and the contact between glacial drift and the bedrock. This represents a significant contribution of interpreted data in areas where typical glacial geology thickness is 600 to 1000 feet, and the current drilling data is only 200 to 400 feet below the surface. Many of these areas contain currently unknown water resources, for both community and industry development, associated with glacial tunnel valleys on the bedrock surface.

MGS also submitted an unsolicited proposal to the Groundwater Protection Council of the National Groundwater Association Groundwater Research Foundation. This proposal presents a demonstration coupling techniques of passive seismic data in areas of little geologic data (drilling and other data) to interpret bedrock depth and possible glacial tunnel valleys. Both the MOGA seismic data and this potential grant may be combined to support a more rapid review of local geology for additional water resources in areas of potential need, as well as for environmental protection.

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The MGRRE core and data repository is the cornerstone of available scientific geologic data for Michigan. MGS is seeking annual state legislative funding for survey staffing, and for core and data repositories that will combine the geologic data resources of MGRRE and establish MTU at Houghton as a data facility.

Attached to this annual report is a summary of all 2015 Michigan geologic research, for all submitted proposals and awards, publications, map products, presentation abstracts, and reports completed by MGS, WMU, and student researchers.

GENERAL SURVEY ACTIVITIES AND ACHIEVEMENTS:

MGRRE – Sample and Data Repository: The Michigan Geological Repository for Research and Education (MGRRE) has served Michigan for over 30 years under the direction of Dr. William Harrison III. It continues to be the primary strength of the MGS. MGRRE conducted Petroleum Technology Transfer Council energy workshops in March and November of last year, with a combined attendance of over 220 professionals and companies.

Listed below are some of the ongoing and most recent achievements that have emerged from the numerous requests and onsite researcher visits for data review at MGRRE:

A collaborative scientific program for carbon sequestration research in oil and gas reservoirs was established and funded by the Department of Energy (DOE). It includes MGRRE, MGS, Midwest Regional Carbon Sequestration Partnership (MRCSP), Battelle National Laboratories, Core Energy, and the DOE. Requests for review of geologic core and other data are incorporated into this program. Technical review of core and related data coupled with field validation progressed significantly this past year. This resulted in the further confirmation of Enhanced Oil Recovery (EOR) programs utilizing the capture and injection of CO₂. The EOR program is one of the tangible economic benefits of carbon capture and injection. It has resulted in the recovery of an estimated 1.6 million plus barrels of incremental oil that was formerly deemed unrecoverable by conventional secondary recovery methods. The program has provided millions of dollars in additional revenue for the Michigan economy, as well as a substantial number of new jobs.

The MGS and MGRRE received incremental funding for core, data storage, and other services through generous donations from industry sources.

MGRRE applied for and received a grant from the National Geological and Geophysical Data Preservation Program (NGGDPP) in support of their data capture and preservation functions. During 2015, 1178 gas chromatograph analyses were scanned and inventoried. These hydrocarbon analyses provide data that can be used to identify prospective wells and zones for secondary recovery, as well as for safe underground CO₂ storage. MGRRE researcher Lolita Krievs categorized, and confirmed well identities and uploaded the data to the National Catalog (<http://ndc.sciencebase.gov>) at the NGGDPP.

MGS continues to emphasize the importance of geologic data and the Return on Investment (ROI) from the systematic retention of core, drill samples, and geologic data in paper format, and its enhanced importance when converted to electronic formats.

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As MGS has noted in previous presentations, Michigan has received hundreds of millions of dollars in oil, gas, mineral revenues, and associated taxes resulting from the geologic sample repository, and the resources and scientific work of the MGRRE facility and staff. Tens of successful student theses, industry research studies, and other geological programs conducted over the last 30 years are also documented, yet as of this date, there has been no direct funding for MGRRE or MGS by the State of Michigan in support of this critical effort.

Geologic Data Base to Support Geologic Resource Assessment Mapping Projects: The governor's Water Use Advisory Council (WUAC), under the direction of the director of the DEQ, completed a two-year review of the water resource issues in the state. One of the issues uncovered by the WUAC was that available geologic data is not being used. The MGS recognizes that there is an abundance of geologic data that is not available for use in assessing our resources, which also includes aggregates as well as groundwater. This situation was presented and is described below.

The State of Michigan has numerous data sets and documents that are either in paper or microfiche format, along with various electronic databases that neither communicate with each other, nor are they retrievable in a uniform electronic format. There could be up to a million data sets that represent geologic information having an estimated minimum value of over \$2.0 billion.

Michigan risks the loss of a substantial portion of these data resources due to physical deterioration, mishandling, and to the expense of physical storage. This is called "orphan data". The inefficiency that is inherent in the use of outdated databases is substantial. The result is that state employees, and the public, spend unproductive time in both retrieving and sorting data before it can be effectively used.

It is obvious that there is a demand for a set of central electronic databases that could be used to archive standard geologic information into formats that are easily searchable and appropriate for the type of information requested. A centralized set of databases would make Michigan's agencies more functional and time responsive. Properly prepared electronically formatted files would also provide the public with an expedited mechanism to fill FOIA requests, or to allow inquiry rather than personally handling paper files. The files would be made available through three electronic steps: request, receive, and review. A searchable electronically formatted document program would encourage greater use of available data, and would save manpower and time for both state employees and public users. For example, many of the databases could be supported by a multi-tiered fee structure, and users would have existing documents almost instantly available. Fees would cover the cost of continuing input and maintenance of data.

Drillers Workshop and a DEQ Geologists Outreach Glacial Core Review: In 2014 and 2015, the MGS proposed a format for data entry by water well drillers to support more consistent, verifiable data for water resource studies. Two workshops and a data test with the DEQ Geologic Outreach confirmed that drillers and users of water well data would appreciate a standardized approach to data notation and entry of drill cuttings information.

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The workshops focused on a standardized approach to classifying water well drill cuttings in order to have more useable data to assess water production zones and other natural resources in shallow glacial deposits. The MGS will be presenting a sample identification training session at the Michigan Groundwater Association (MGWA) new drillers training program in February 2016. A standard approach to the logging of drill cuttings is a way for MGWA members to add real value to the non-standard datasets that exists today.

Oil and Gas: The MGS through the Resource Center at MGRRE continues to be associated with the Petroleum Technology Transfer Council (PTTC). For more than 25 years, MGRRE has conducted both one- day and multi-day workshops focused on oil and gas information and technologies. The two workshops offered during 2015 had over 220 participants. These workshops focus on relevant scientific exploration and production topics in the energy industry.

MGS and MGRRE Websites: The number of contacts (hits) on a website is a measure of the importance of that information resource. The MGRRE and MGS website contacts indicate greater visibility with an increased public exposure and an increased number of data sets. Between 2012 and 2014, the number of unique requests at the MGRRE website (different ID for each request) increased from 17,838 to 27,425. The total of unique ID requests for 2015 was 30,513, a tribute to the relevance of the MGRRE information. The MGS website has been fully functional for the last two years and the number of unique ID requests was at 3,114, approximately 260 per month.

Geologic Mapping: The MGS participates in, and submits projects in both of the USGS Federal Geologic Mapping Programs, STATEMAP, and Great Lakes Geologic Mapping Coalition projects under the direction of Dr. Alan Kehew. This past year, the USGS mapping program awarded funding to map areas in both the Lower Peninsula, under the direction of Dr. Alan Kehew and John Yellich, and in the Upper Peninsula, under the direction of Dr. Joyashish Thakurta. The emphasis in the two USGS mapping programs is concentrated in the areas of mineral resources for the Upper Peninsula, and for state-wide, aggregate and water resources. The need for accurate geologic data and aquifer characterization in the LP cannot be underestimated. The LP studies are being conducted with an introduction to a refined 3-D approach that includes a combination of surface geologic mapping combined within a limited rotosonic and geoprobe drill coring program. The refined geologic mapping approach includes core samples and sieve analyses, down-hole geophysical logs, and validated geologic logs from water well drillers. The combination of these components with available LiDAR imagery results in a more accurate geologic depiction of an area's surface topography and its stratigraphic section. This increases the quality of the data used in assessing the potential areas for aggregate resources, the underlying water-bearing strata, and the potential availability of water for high production users such as the agricultural community. Quality LiDAR, if available, also allows for a more rapid assessment of the geology of areas where physical access maybe limited, and where field validation can be focused on mapping the continuity of the geology.

Groundwater Resources & Environmental Quality and Energy: The MGS has been asked to sit on the Michigan Governor's Water Use Advisory Council. The council supports the adoption of

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the Great Lakes Compact that requires permitting of large capacity water wells, and quantifies their impact on local stream flows. Local requests are being made to the MGS for information on the quality and quantity of the groundwater in certain areas of the state, but many of the requests cannot be supported by MGS, because the local or personal request does not have funding associated with any proposed study at this time.

Economic Geology: Dr. Joyashish Thakurta, the Geosciences Department economic geologist / petrologist, has focused his research on the igneous and metamorphic rock suites of the Upper Peninsula of Michigan. His current UP research efforts are integrated into an overall program of mapping, sample collection, and geochemical analysis of little known geologic environments. He has written proposals to conduct research with mining companies that will allow students to sample and analyze data for their respective theses. As previously noted, MGS has been spearheading the endorsement of a USGS funded aeromagnetic demonstration project to be located in an area of buried Precambrian rock types that may contain minerals of economic importance. Dr. Thakurta has been surface mapping in parts of this proposed demonstration area. The combination of these two programs offers the potential to stimulate exploration that would benefit the leasing of state and private land containing a potential for buried mineralization targets.

GIS Data Management and MGS Store: MGS continues to format new and historic maps and other documents to comply with ArcGIS standards. These documents will be archived into the MGS Data Management system. This new role of the MGS has already been initiated, and it includes the preparation of documents and maps for distribution and sale through the MGS website. The MGS believes that there are many older Michigan publications and paper resources that need to be acquired and archived, in order that they can be made available to the scientific community and to the general public.

Outreach and CoreKids K-12 program: The CoreKids K-12 program at MGS-MGRRE has had increasing interest by the Michigan education community under the direction of Dr. Peter Voice. The program emphasizes the importance of earth science education of middle and high school students, and has evolved to include informing the adult community. Many teachers are now turning to the educational resources at the MGS-MGRRE facility and CoreKids. The number of contacts being made with students or with the general public at informal presentations, special events, or school sessions, has continued to be a success during the past year. With the help of many student colleagues they present interactive classroom modules explaining Michigan's geologic history, natural resources, and hydrogeology. The program visited a number of schools over the last three years. Coupled with specific allied partners, the earth science related events such as the Michigan Department of Environmental Quality and the Kalamazoo Geological and Mineral Society Annual Show, the CoreKids program had 50 events this year. The program has also expanded to the eastern part of the state. Teachers are realizing the benefits of this program, and the MGS hopes to incorporate it into the State K-12 program going forward. Over the past 36 months, the program has interacted with 42,719 people including K-12 students, college students, teachers, professional geologists, and the general public.

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CoreKids has cultivated allied partnerships over this three year period. As a result, there is now a total of seven partners, which include the University of Michigan, the Detroit Museum of Natural History, the Michigan State University Museum, the Michigan Mineralogical Society, and the Central Michigan Lapidary and Mineral Society. The program continued its association with the Cranbrook Institute of Science, the Kalamazoo Air Zoo, and the Kalamazoo Geological and Mineral Society. In addition, the CoreKids program strengthened its ties with the state teachers associations (Michigan Earth Science Teachers Association [MESTA] and Michigan Science Teachers Association [MSTA]).

Dr. Peter Voice co-chaired the GO-MPS (Geological Outreach-Museums, Parks, and Surveys), that was initiated by Lisa Anderson, a WMU Geosciences Graduate, at the Geological Society of America (GSA) North-Central meeting in Wisconsin. The WMU contingent of Dr. Voice and Dr. Heather Petcovic made two presentations on, "Developing an online education portal using the MGRRE resources" and the CoreKids module, "Hydraulic Fracturing" model respectively. Dr. Voice will be co-chairing the GO-MPS session in 2016 in Urbana-Champaign, Illinois with Lisa Anderson,

The CoreKids program received a generous gift of \$5,000 from the American Association of Professional Geologists, and appreciates the generous support of \$18,000 received from the American Petroleum Institute Michigan Section in 2014 to support our operating expenses in 2015. The CoreKids program also submitted a National Science Foundation (NSF) proposal to support an online education portal focused on the resources of the MGRRE facility in the amount of \$450,000. This proposal was submitted in October 2015.

Remote Sensing: The MGS and the Remote Sensing Laboratory under the direction of Dr. Mohamed Sultan is preparing proposals to support satellite imaging and airborne geophysical surveys for mapping faults, karst features, water resources, and other geological features. The primary emphasis has been in areas outside of the U.S., however, recent studies are being initiated for validation in the U.S. using tested, and proven, remote sensing techniques.



Attachments:

MGS/WMU 2015 Publications and presentations

MGS- Resource Centers

MGS – Advisory Council

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MGRRE Geosciences, WMU and Michigan Geological Survey Professional Activities Report for 2015

Michigan Related Research Grants and Contracts (~ \$508,301 in research grant funding received in 2015)

Harrison, William B., III, 2015, Michigan Contribution to the National Geothermal Data System – Installing Software for Metadata Management, Funded by Arizona Geological Survey, \$9,000

Harrison, William B., III, 2015, National Geological and Geophysical Data Preservation Program Funded by United States Geological Survey, \$35,639

Barnes, David A. and William B. Harrison, III, 2014 to 2017, Reservoir Characterization and Petrophysical Studies in Niagaran-Silurian Northern Lower Michigan, Midwest Regional Carbon Sequestration Partnership, Phase III, Budget Period 4, Funded by Battelle Memorial Corp. (approximately) \$150,000 per year

2015-17 “The influence of road salt deicers on the chemistry of Michigan lakes”, Michigan Department of Environmental Quality (co-PI’s:Dr. Carla M. Koretsky & Dr. Kathryn Docherty), \$32,262

Kehew, A. E. and Yellich, J.A.; USGS Great Lakes Geologic Mapping Coalition, Surficial Geologic Mapping Cass County, Michigan; two mapping projects; 1. Jones 7 1/2 Minute Quadrangle, and continue Barry and Calhoun County composite maps; and .2. Vandalia 7 ½ Minute Quad to initiate a county composite map,. 2016-17; \$72,500 USGS award for the two projects

Yellich, J.A.; MDEQ, MDNR, , Office of Great Lakes will support the Vandallia mapping project in the amount of \$44,000,the first State funds since the USGS program began, to match Federal funds

Yellich, J.A.; Sultan, M.; **Emil, M.** 2015, Assessment of the Spatial and Temporal Subsidence (Sinkholes) Patterns and Controlling Factors in Qatar: A Radar Interferometric Approach \$135,000, Contract Pending.

Kehew, A.E. and Thakurta, J.; USGS STATEMAP National Geologic Mapping program awarded 2016- 2017 funding to Surface Geologic Map: Duck Lake and Springport 7.5 Minute Quadrangles, Calhoun and Eaton Counties; and Surficial Geologic Map: Norway and Bessemer 7.5 Minute Quadrangles, Dickinson and Gogebic Counties, Michigan, in the amount of \$104,000 for both projects.

Yellich, J.A., MDEQ-WRD, Groundwater Quality Monitoring Strategy, 24 month, August 1, 2015 to July 31, 2017, \$121,800

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USGS Quadrangle Maps produced and published in 2015:

Esch, J.M. and Kehew, A.E., 2015, Surficial Geology of the Olivet 7.5 Minute Quadrangle, Calhoun and Eaton Counties, Michigan, Surficial Geologic Map Series SGM-15-01, scale 1:24000

Thakurta, J., Surficial Geology of the Vulcan 7.5 Minute Quadrangle, Dickinson County, Michigan; Michigan Geological Survey, Surficial Geologic Map Series SGM-15-02, Scale 1:24,000

Linker, J.S., Kehew, A.E. and Esch, J.M. 2016, Surficial Geologic Map of the Tekonsha 7.5 minute quadrangle, Michigan. Michigan Geologic Survey Surficial Geologic Map Series SGM-15-03 1:24,000 scale.

Kehew, A.E. and Esch, J.M. 2016, Surficial Geologic Map of the Union City 7.5 minute quadrangle, Michigan. Michigan Geologic Survey Surficial Geologic Map Series SGM-15-04.1:24,000 scale.

Kehew, A.E. and Esch, J.M. 2016, Surficial Geologic Map of the Burlington 7.5 minute quadrangle, Michigan. Michigan Geologic Survey Surficial Geologic Map Series SGM-15-05.1:24,000 scale.

Proposals submitted in 2015 and still pending, funding would be in 2016 and 2017

Surficial Geologic Mapping: Adamsville and Mottville 7.5 Minute Quadrangles, Cass County, Michigan, Kehew, A.E and Yellich, J.A.; \$135,742 .

Bedrock Geologic Mapping: Felch 7.5 Minute Quadrangle, Dickinson County and Surficial Geological Mapping: Iron Mountain 7.5 Minute Quadrangle Dickinson County, Michigan and Florence County, Wisconsin; Thakurta, J., \$103,870.

National Science Foundation (NSF) proposal to support an online Education Portal focused on the resources of the MGRRE facility - \$449,980.

Ground Water Protection Council (GWPC) – Groundwater Research and Education Foundation – “Develop a geophysical and geologic tool to identify, characterize and support management of deep groundwater resources found in bedrock or glacial valleys buried in glacial terrains in the State”, a proof of concept proposal in Calhoun County – \$99,585.

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Published Abstracts of Professional Presentations - 2015

(Student Authors are Highlighted in Bold)

Harrison, III, W.B., **Cameron Manche** and **Nicholas Panyard**, 2015, Antrim Shale Natural Gas Play in Michigan: 30 years Later, A Retrospective, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Manche, Cameron J. and William B. Harrison, III, 2015, The Effects of Structural Lineament Reactivation on Antrim Shale Natural Gas Development, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Voice, Peter and William B. Harrison, III, 2015, A Time-Transgressive Model for the Burnt Bluff Group: New Insights from Outcrop and Subsurface samples, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Garrett, Jon and David A. Barnes, 2015, Petrophysical Characterization of a Niagaran-Salin Reef Complex Reservoir; Kalkaska 21 Field, Kalkaska Co., Northern Lower MI, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Cox, Kyle J. and David A. Barnes, 2015, Anomalous Thermal Indicators from Authigenic Minerals in the Upper Paleozoic Strata of the Michigan Basin, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Sattler, Frank, 2015, Lithologic Properties of the Upper Ordovician Utica Formation, Michigan basin, USA: A Geological Characterization and Assessment of Carbon Dioxide Confinement Potential from mechanical and Petrophysical Properties, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Rine, Matthew, David A. Barnes and William B. Harrison, III, 2015, Petrophysical and Stratigraphic Characterization of Michigan Silurian Reefs, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Adducci, Joseph G. and David A. Barnes, 2015, Geological Controls on Stratigraphy and Sedimentation of the Mississippian Marshall Formation, Michigan Basin, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

Panyard, Nicholas R., 2015, An Integrated Geochemical Model using Sulfur and Organic Carbon for the Late Devonian Antrim Shale, Michigan Basin, USA, Abstract of Presentation, Eastern Section AAPG 44th Annual Meeting, Indianapolis, Indiana, September 20-22, 2015.

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Rine, Matthew, David A. Barnes and William B. Harrison, III, 2015, Evaluating the Sequence Stratigraphic Relationships, Lithofacies and Petrophysical Properties of the Silurian (Niagaran) Reefs for the Purpose of CCUS and EOR in the Michigan Basin, North Central Section, Geological Society of America, 49th Annual Meeting, Madison, Wisconsin, May 19-20, 2015, Abstract of Poster Presentation.

Petcovic, Heather, Peter Voice, William Cobern, Brian Horvitz, William B. Harrison, III, and Andrew P.K. Bentley, 2015, Involving Stakeholders in Developing Web-Based Outreach Resources: An Example from the MGRRE Education Portal, North Central Section, Geological Society of America, 49th Annual Meeting, Madison, Wisconsin, May 19-20, 2015, Abstract of Oral Presentation.

Peter Voice, Gilchrist, Ann M., Petcovic, Heather, William B. Harrison, III, 2015, A Demonstration Model of Hydraulic Fracturing: Hands-On Analog to Fracturing Shale, North Central Section, Geological Society of America, 49th Annual Meeting, Madison, Wisconsin, May 19-20, 2015, Abstract of Oral Presentation.

Kehew, Alan E. and John Esch, 2015, Frank Leverett's Description of the Saginaw Lobe Terrain in Southern Michigan: How Does it Stand Up Today?, North Central Section, Geological Society of America, 49th Annual Meeting, Madison, Wisconsin, May 19-20, 2015, Abstract of Oral Presentation.

Kehew, A. E., Esch, John M., Linker, John S., Kozlowski, Andrew L., Woolever, Caleb, **Ewald, Stephanie K., Guzman, Ivan and Karki, Sita**, 2015, A New Geologic Map for Barry County, Michigan, Geological Society of America *Abstracts with Programs*. Vol. 47, No. 7, p.120

Hussien, H.M., Kehew, A. E., Aggour, T.A., Korany, Ezzat A., Abotalib, Z.A., Abdelmohsen, H., Morsy, S.M. and Rabie, M. 2015. An Integrated Approach (Remote Sensing, Geophysics, Stable Isotopes, Field and Hydrochemistry) for Identification of Potential Aquifer Zones in Wadi Qena Basin, Easher Desert Egypt, Geological Society of America *Abstracts with Programs*. Vol. 47, No. 7, p.749

VanderMeer, Sarah M. and Kehew, A. E. 2015. Surficial Mapping of Pictured Rocks National Lakeshore, Michigan, Indian Town, 7.5-Minute Quadrangle. Geological Society of America *Abstracts with Programs*. Vol. 47, No. 7, p.114

Thakurta, J., **Haynes, J. and Boxleiter, A.** (2015) The Sturgeon Falls gabbroic intrusion and its relation with the metalliferous sulfide rocks of the Penokean Volcanic Belt, Geological Society of America *Abstracts with Programs*. Vol. 47, No. 7, p.677

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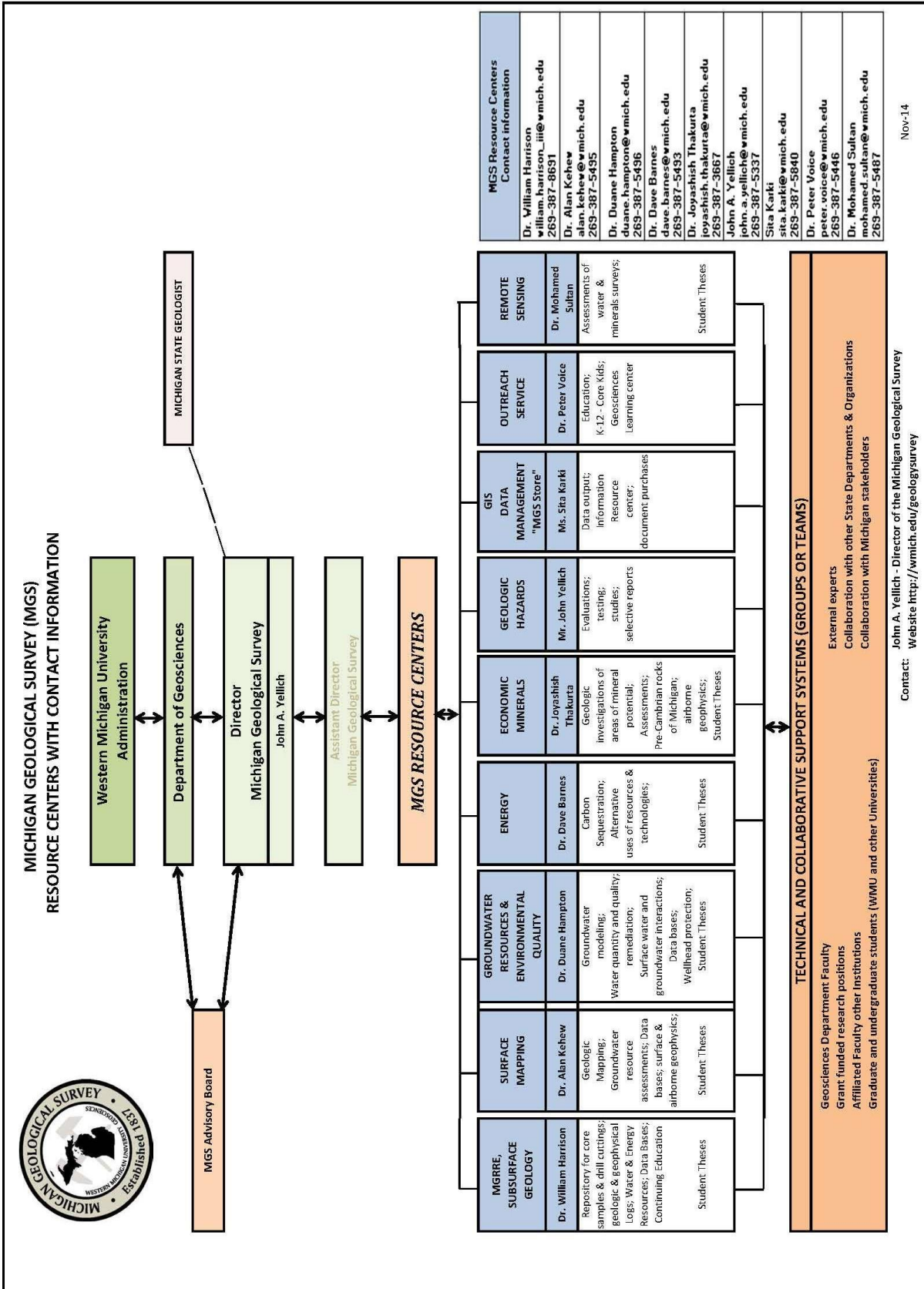
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