Title: **Precambrian Basement Topography using 3D Modeling of Gravity and Aeromagnetic Data in Southeastern Wisconsin and Fond Du Lac County**

Project I.D.: DNR Project # 193

Investigators: Principal Investigator – John Skalbeck, Associate Professor, University of Wisconsin-Parkside, Department of Geosciences
Research Assistants – Adrian Koski, Undergraduate Interns, University of Wisconsin-Parkside, Department of Geosciences

Period of Contract: July 1, 2006 through June 30, 2008

Background/Need: Increased concerns about groundwater resources in Wisconsin have brought about the need for better understanding of the subsurface geologic structure that lead to developing conceptual hydrogeologic models for numerical simulation of groundwater flow. Models are often based on sparse data from well logs usually located large distances apart and limited in depth. Model assumptions based on limited spatial data typically requires simplification that may add uncertainty to the simulation results and the accuracy of a groundwater model. This research provides another tool for the groundwater modeler to better constrain the conceptual model of a hydrogeologic system. The area in southeastern Wisconsin near the Waukesha Fault provides an excellent research opportunity for our proposed approach because of the strong gravity and aeromagnetic anomalies associated with the fault, the apparent complexity in fault geometry, and uncertainty in Precambrian basement depth and structure. Precambrian basement surface throughout Fond du Lac County is known to be undulated and this uneven basement topography controls water well yields and zones of stagnant water. Therefore, an accurate estimation of the basement topography in Fond Du Lac County is vital to determining ground water flow and quality of groundwater in this region.

Objectives: The objectives of this research are to improve the current understanding of the subsurface Precambrian basement topography in southeastern Wisconsin and in Fond Du Lac County. Results from coupled modeling of gravity and aeromagnetic data along profiles (Skalbeck et al., 2007) in this area show that the estimated bedrock surface is uneven on both sides of the Waukesha Fault. Although, this modeling greatly improved our understanding of Precambrian bedrock topography in southeast Wisconsin, detailed estimation of this surface is limited by the 10 km spacing between profiles. The 3D modeling of gravity and aeromagnetic data from this study provides an even better definition of the Precambrian bedrock surface topography and the fault geometry because the model grid density is much greater (1 km grid) relative to the profile separation. The second objective it to provide a better estimate of the uneven Precambrian basement topography that has been documented throughout Fond du Lac County (Smith, 1978; Newport, 1962). Because basement surface relief is dramatic over short lateral distances in Fond du Lac County, 3D modeling of gravity and aeromagnetic data is particularly well suited for this area. Study results yield highly constrained subsurface Precambrian elevation maps for southeastern Wisconsin and Fond du Lac County that may be valuable for refining existing numerical groundwater models.

Methods: Three dimensional (3D) models of the Precambrian basement were developed by modeling existing gravity and aeromagnetic data using computer software GMSYS-3D and Oasis Montaj. The models are constructed with 1000 m grids for each data set and each geologic unit. Initial density and magnetic susceptibility values for the layers were obtained from modeling results in southeastern Wisconsin (Skalbeck et al., 2007). Blocks were assigned constant density and magnetic susceptibility or internal variance of these physical parameters calculated by GM SYS 3D. The forward modeling option of GM-SYS 3D is used initially to calculate the model anomaly and it statistics relative to the observed anomaly. The inverse modeling option is used for the remaining model runs to adjust the geologic model surface elevation and the block density or magnetic susceptibility values o optimize the model calculated anomalies to the observed gravity and magnetic anomalies. We employed a modification of model acceptance criteria from previous studies (Skalbeck, 2001; Skalbeck et al., 2005; Skalbeck, 2007) by using percent standard deviation ([% SD]; SD/ anomaly range]).

Results and Discussion: The initial 3D models for southeastern Wisconsin and for Fond du Lac County using constant density and magnetic susceptibility values for the Precambrian basement with no well constraints produced unacceptable fit statistics. Subsequent model runs incorporating well constraints, variable density and magnetic susceptibility, and a surface representing mafic bodies beneath the Precambrian basement produced fit statistics for both study area models. The 3D model for southeastern Wisconsin agrees well in overall geologic structure with the modeled Precambrian basement from Skalbeck et al. (2007) but the new 3D model shows more detail. Both models show a similar trend of the Waukesha Fault; however, 3D model shows an elevated area near the southern end of the end of the Waukesha fault. The new 3D model shows slightly less variation in overall model elevations and less undulation on the up-thrown block northwest of the fault. For the Fond du Lac County model, a comparison of Precambrian basement elevations from model verification wells with elevations obtained from the 3D model shows close agreement. The mean difference between well log and 3D model elevations is 3 m in which is less than 1 % of the range. A comparison between the basement elevation map from well logs and from the 3D model combined with well log elevations illustrates that both surfaces exhibit similar overall basement structure but the new 3D model shows much greater detail. Much more undulation is present on the basement ridge located in the western portion of the study area. The largest difference between the two surfaces occurs in the northwestern and southwestern corners of the area where no well elevations exist.

Conclusions/Implications/Recommendations: The results of this study demonstrate that 3D modeling of existing gravity and aeromagnetic data combined with existing well log data yields a more detailed delineation of the subsurface Precambrian basement topography relative to well log data alone. The 3D model for southeastern Wisconsin is consistent with the overall structure of the Skalbeck et al. (2007) model but shows greater detail with regard to undulations in areas between the previous model profiles. The 3D model also shows the Waukesha fault more sharply defined while matching trend the previous model. This 3D model for Fond du Lac County is able to provide detail of the basement surface in areas with no well control that is consistent with gravity and aeromagnetic anomalies. The rich set of well log data that documents the basement elevation in the county allows for a highly constrained 3D model that is verified relative to a large set of well elevations. The comparison between the model calculated and well log elevations confirms that the 3D model provides reasonable prediction of the basement topography.

Related Publications:

Koski, A.J. and Skalbeck, J.D., 2008, Estimation of basement topography in southeastern Wisconsin using 3-D modeling of gravity and aeromagnetic data, Data [abs.], *American Water Resources Association-Wisconsin Section, 32th Annual Meeting Program and Abstracts*, p 31.

Peterson, M.T., Koski, A.J. and Skalbeck, J.D., 2008, Estimation of basement topography in Fond du Lac County using 3-D modeling of gravity and aeromagnetic data, Data [abs.], *American Water Resources Association-Wisconsin Section, 32th Annual Meeting Program and Abstracts*, p 33.

Key Words: Hydrogeology, gravity, aeromagnetic, modeling, Precambrian

Funding: Wisconsin Department of Natural Resources

Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.