Editor's Message

Scientific visualization in hydrogeology

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Three-dimensional (3D) visualization in hydrogeology is no longer a mere extravagance. It is regularly employed as a tool of analysis and communication. With the advent of powerful personal computers, fast graphics displays, and a variety of graphical and geographic information system software, significant visualization capabilities are readily available to hydrogeologists. Realistic 3D images may be created of hydrogeologic structure, locations of wells, surface-water bodies, and other pertinent objects in a field area. When 3D distributions of groundwater properties such as head, solute concentration, or temperature are superimposed on

such an image, the hydrogeologic features and parameters of importance to a groundwater resource become apparent. More and more 3D simulation analyses of groundwater flow and transport are being carried out, and 3D visualization is often the tool of choice for inspecting and understanding model results.

Indeed, 3D hydrogeologic visualization of field areas and modeling results will soon become the norm. Any new technology brings advantages and some pitfalls, and this one is no exception. The major advantages involve the use of visualization in education and building of hydrogeologic intuition. Often, the public is largely

Figure 1

Figure 3

Figure 2

unaware of the water resources beneath its feet and of the role groundwater plays in quality of life. 3D visualization and animation can successfully communicate concepts to the public through compelling images where the use of too many explanatory words would fail. The meaning of 3D images is easily absorbed even by school children, making it possible to teach hydrogeologic concepts early. We know that hydrogeology is by no means an exact science, and that the perverse combination of sparse data and subsurface structural complexity that regularly faces the hydrogeologist requires development of intuition and experience regarding field interpretations. Inspection of 3D visualizations of field data, subsurface structure, and modeling results is a powerful means of building such intuition.

A pitfall in modern visualization is that 3D color images may appear impressive despite a lack of good data or model results as their basis. The spatial interpolation and extrapolation among sparse data routinely provided within the graphics software can create complete-looking images from very little real information. However, as we gain experience in viewing 3D hydrogeologic images, we may become less inclined to believe misleading images merely because they are visually compelling, and we will learn to question and judge this medium more effectively.

Three example 3D images are shown here, and you can find other images and animations on the *Hydrogeology Journal* (HJ) page of the Springer LINK site (link.springer.de/link/service/journals/10040/index.htm) the site where HJ authors may place Electronic Supplementary Material for their published articles. The three images presented here were created with three different graphics packages. *Figure 1* shows solute concentration in a 3D SUTRA code simulation (water.usgs.gov/software/ground_water.html) (run by C. Simmons, Flinders University, Australia, and A. Provost, USGS),

wherein high-density brine plumes gradually grow downwards from a saline surface-water body through initially fresh groundwater. The image was created using the free software library VTK (www.kitware.com/vtk.html) with a C++ driver code (written by P. Hsieh, USGS).

Figure 2 shows a hydrogeologic structural model (2 km by 2 km by 1 km deep) of fracture zones in granodioritic rock below an island on the southeastern coast of Sweden (by S. Tirén and P. Askling, Geosigma AB, Sweden, and C. Voss, USGS). The image, developed for a nuclear waste repository study, was created using the powerful Bentley MicroStation code (www.bentley.com) which costs a few thousand US\$.

Figure 3 shows a 128-km by 80-km region of Illinois, USA, exposing to view an important local aquifer consisting of up to 30–40 m of buried Quaternary sediments that were deposited on the bedrock surface (D. Soller and S. Price, USGS; and R. Berg and J. Kempton, Illinois State Geological Survey); (more information and images are at ncgmp.usgs.gov/ecill). The stratigraphy was interpreted from borehole data, and the image was created using the sophisticated Dynamic Graphics EarthVision code (www.dgi.com), which costs a few tens of thousands of US\$. Other excellent software packages are also available.

On the HJ Springer LINK site, you will find some example images in a Powerpoint slide show, an image of *Figure 1* (as a VRML file) that you can rotate in 3D using your Web browser, and an animation of the simulation from which *Figure 1* was selected. I urge readers to send to the Editor other examples of scientific visualization, both good ones and obviously bad ones, with very brief explanations. Selected images will be added to this LINK page as a temporary collection of examples of scientific visualization in hydrogeology.