Making 3-D Geologic Maps of Seattle

O'Neal, M.A., K. Goetz Troost, D.B. Booth, S.A. Shimel and E. Sommargren
University of Washington, Dept. of Earth and Space Sciences, Box 351310, Seattle, WA 98195-1310; E-mail: M.A. O'Neal at maoneal@u.washington.edu

Overview. The Seattle-Area Geologic Mapping Project (SGMP) was initiated in 1998 through collaboration with the U.S. Geological Survey and the City of Seattle (City) to provide comprehensive acquisition and interpretation of geologic data for the City. From that initial focus, the project has grown to include other geographic areas and a broadened range of research interests. The current goals of the project are to acquire existing geologic data and create new geologic information in the central Puget Lowland; to conduct geologic research and produce new geologic maps across this geographic area; and to support the wide variety of additional research, hazard assessments, and land-use applications of other agencies and private companies throughout the region. These goals are being met through the development of a comprehensive geologic database, published geologic maps, and construction of three-dimensional geologic maps and models.

Why 3-D mapping in Seattle. 3-D geologic mapping is being undertaken in Seattle because of the recognized need to identify, characterize, and mitigate for geologic hazards. Extensive efforts to make earthquake ground shaking maps and landslide hazard/probability maps necessitate detailed subsurface geologic information. Meetings with users' groups have also echoed the need for 3-D compilations to better delineate the hazard-susceptible geologic contacts and materials.

In addition, sufficient data are available to support a 3-D mapping effort in Seattle, providing an opportunity to evaluate whether the increased level of effort needed to produce such maps achieves a corresponding improvement in the accuracy and utility of subsequent hazard maps. Throughout the City, extensive urban development coupled with variable geology produces a wealth of subsurface data, primarily in the form of geotechnical borings. For example, the density of borehole data in downtown Seattle reaches 350 borings per ¼ section and in outlying urban areas averages 50 borings per ¼ section. Geotechnical borings are logged by geologists or engineers and are based on core samples, often enhanced by geotechnical laboratory testing. Thus each of these explorations usually contains detailed descriptions of lithology and material strength.

Project approach. Traditional geologic mapping in the Seattle area is difficult because of urban development and the resulting paucity of exposed geologic materials; however geotechnical explorations are abundant. Most of these data are poorly organized and widely scattered in building and utility departments, transportation agencies, and the archives of private consulting firms. A primary goal of the SGMP is to consolidate, organize, and standardize this information into a publicly available database. To date, geologic data and interpretations from nearly 40,000 field explorations, exposures, and excavations have been entered into a GIS-based relational database created using Oracle database software, ESRI Spatial Database Engine (SDE), and ESRI ArcView to efficiently store, manipulate, and display this existing body of Seattle-area subsurface geologic data. The downhole data is easily viewed in two or three dimensions using ArcView and custom stick-log and cross-section display tools. An initial byproduct of this digital acquisition and display of borehole data has been a streamlined process for surface map creation. Given the quantity, density, and quality of the subsurface data, we have high confidence in the resulting surface maps and can demonstrate significant improvement over prior published maps of the region. Currently, we have three maps of the Seattle area completed and two additional maps currently in preparation. The surface maps and borehole data are transferred into EVS where solid models are being developed for application to problems in groundwater flow or ground shaking analysis conducted by other scientists.

Despite the broad spatial distribution of the down-hole data, the limited depths of most borings do not facilitate either automated interpretations of the subsurface geology or spatial interpolation of material properties. Major transit and sewer projects provide excellent but very widely spaced transects of deep, high-quality borehole data for ground truthing between outcrops. Therefore, we are not modeling the contents of the database directly. We are, however, interpreting each lithologic layer in each borehole by assigning stratigraphic units that can then be mapped individually. The surface maps, in combination with their supporting information from the database, provide an excellent foundation for developing 3-D geologic maps, where the nature and location of subsurface geologic contacts are constrained by borehole interpretations and the known or inferred processes of deposition. The geologic maps of the subsurface can be attributed with the properties of the sediments with which we are familiar from surface exposures and geotechnical data. These 3-D geologic maps can subsequently be used to construct a subsurface model.

Creation of a subsurface model would be impossible without this map-making sequence, since deep borings that *could* permit direct spatial interpolation between observed localities are too widely spaced for the degree of geologic complexity. This process results in a model of the subsurface that makes full use of geologic interpretation. In the absence of our work and products, other investigators would still make models but their subsurface representations would lack the local and regional perspective that a densely populated database provides.

Lessons learned. One of the most important lessons learned thus far is that there is community-wide support for such a major undertaking. Had we the ability to predict the project's popularity and our resulting growth, we would have been well advised to start with more robust hardware and software. The project was initiated with a cost-effective mechanism for storing geologic and spatial data in a split fashion, using Microsoft Access and ESRI ArcView; this approach resulted in a data-entry and retrieval design that was flexible and programmable but limited by the rate of spatial data entry and outgrown within a few years. The financial obligations of starting a project with the hardware and high-end software necessary to overcome these problems were not apparently justifiable for our startup, but they have left a legacy that has made our expansion to current levels more difficult than originally anticipated. During this initial period, we also chose to focus primarily on acquiring data, building a user-friendly database, and developing protocols for geologic interpretation. This emphasis, while leading to better geologic maps and a more robust database, slowed the production of the initial maps; we anticipate, however, that they will expedite the production of all future maps.