

The Seattle-area geologic mapping project and the geologic framework of Seattle

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Introduction

The Puget Lowland is in a unique geologic setting: near a subducting tectonic plate and having been glaciated over 6 times in the last 2 million years. Because of this setting, the Puget Lowland is subject to abundant geologic hazards, such as volcanic activity, earthquakes, faulting, landslides, liquefaction, and other ground failures. Because of the cost of damage that can result from geologic hazards, the City of Seattle and many other agencies want to mitigate for geologic hazards. Recent events have demonstrated the need for such concern. The M-6.8 Nisqually earthquake occurred on Feb 28, 2001 with an epicenter about 50 kilometers from Seattle, and caused damage to buildings, bridges and lifelines. Earthquake-induced ground failures correlated to local soil conditions and included landslides, loss of bearing strength, and lateral spreading. The estimated cost of damage exceeded 2 billion dollars.

Enormous research efforts -- involving scientists from the University of Washington (UW), other universities, U.S. Geological Survey USGS, City of Seattle, WA DNR, local agencies, and private businesses -- are focused on identifying geologic hazards in Puget Sound. These efforts include: geologic mapping, geophysics to identify bedrock structure, upgrade of our seismic network, paleoseismology, identifying properties of geologic materials, age determinations, landslide mapping and modeling, high-resolution bathymetry, and volcanic hazard assessment.

The Seattle-Area Geologic Mapping Project

A collaborative research project was started in 1999 at the UW with the USGS and the City of Seattle. The goal of the Seattle-Area Geologic Mapping Project is to develop a comprehensive geologic database and set of geologic maps to support hazard assessments and land use decisions.

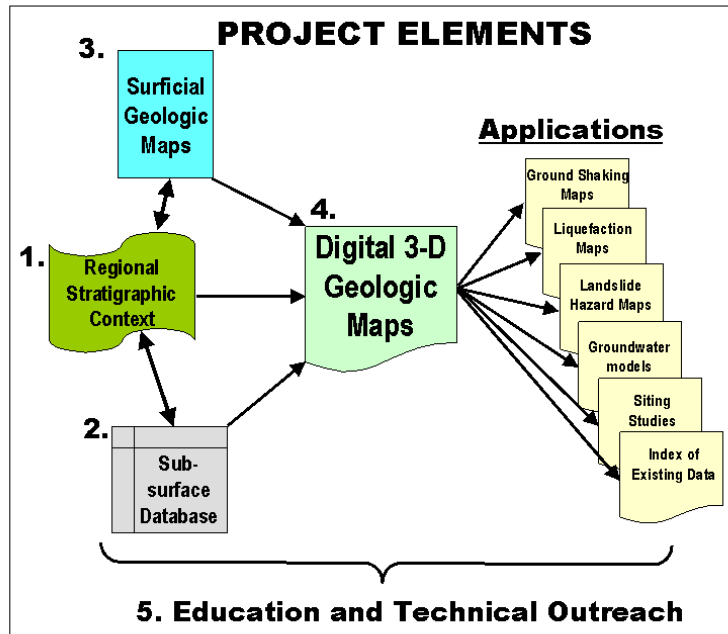
The only available geologic mapping of the City itself is over four decades old. None of the active faults in the region, one of which is now known to pass directly under the City and to have produced violent shaking and ground rupture about 1100 years ago, are even recognized on the existing map. This project will rectify this shortcoming by developing a detailed understanding and representation of the three-dimensional distribution of geologic materials beneath Seattle and to embed that information in the context of a coherent, regionally integrated geologic framework for the south-central Puget Sound region. The new maps are just the beginning. All of the research efforts focused on hazards have and will continue to result in new findings on the geology and tectonic setting of the Lowland.

The project has five components, each designed to address specific objectives:

1. Regional Stratigraphy/Chronology/Training

- Determine age and identification of Quaternary units to help unravel the deformation history.

- Provide detailed descriptions of the Quaternary units and their properties (strength, thickness, lithology, source [volcanic mudflow], etc.) for use by planners, engineers, and consultants.
- Standardize nomenclature for all the geologists working in the Puget Lowland and train other geologists, unfamiliar with Puget Lowland geology.



2. Surficial Geologic Maps Across the Central Puget Lowland

- New geologic map coverage at 1:12,000 scale, in four quads, for the City of Seattle. The maps are being produced (digitally and hard copy) on shaded DEM bases showing all data points (outcrops and borings).
- Continued production of new geologic maps at 1:24,000 scale from the south-central Puget Lowland

3. Subsurface Database for the City of Seattle

- GIS-based compilation of existing geotechnical data and new outcrop data, ultimately maintained by the City and available to the public in perpetuity.

4. Three-Dimensional Geologic Model of the City of Seattle

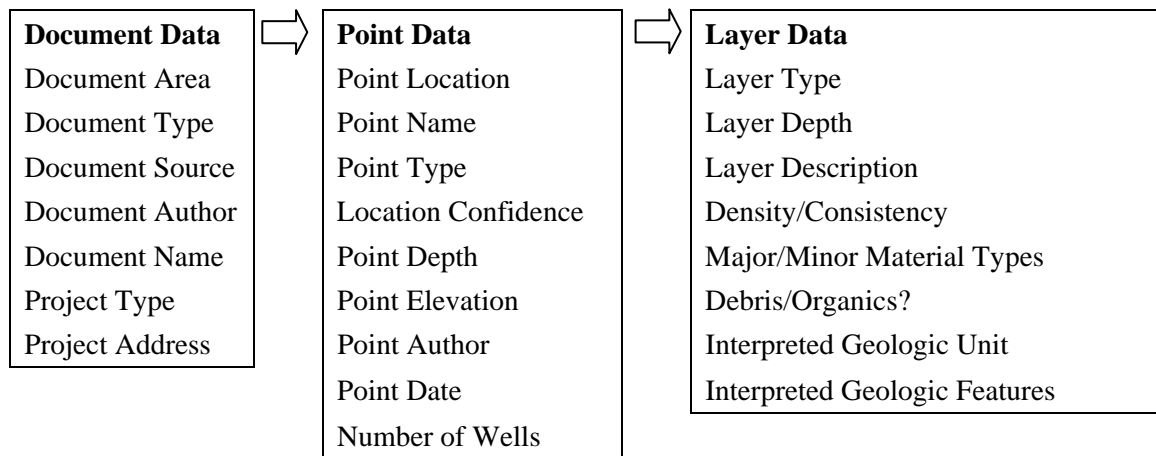
- Geologic interpretation of the subsurface database, integrated with other project components into a graphically supported geologic database and map display, supported by and available from the City of Seattle in collaboration with the University and the USGS.

5. Education/Technical Outreach

- A Technical Advisory Group, assembled to ensure that the database suits current and future needs, has been formed to support these tasks. Its membership emphasizes senior members of the region's geologic and geotechnical community, both private and public.
- Lead, convene, and participate in seminars, conferences, workshops to educate the scientific and nontechnical community about the baseline geologic setting
- Prepare a book, for the public, on the Geology of Seattle.

Database

For the Seattle Geologic Mapping Project, we have developed, and are now populating, a relational database of existing subsurface geologic data that covers the City of Seattle. This database accommodates both spatial and nonspatial data by following a GIS-based approach. The database is designed to accept new data types as they become available, and serves as a template as our project expands its geographic coverage. The database includes fields for the “raw” data as well as fields for geologic interpretations and for the “metadata” that carries information on original source documents, original scale, and anticipated data quality. We have adopted a basic three-level structure for the core of the database, and a simplified listing of the main tables is shown below. We have been working in MS ACCESS but are planning to change to ArcSDE with an Oracle database backend.



Mapping Examples

Comparison of the existing geologic map for the City of Seattle (Fig. 1) with the new mapping of the Seattle Geologic Mapping Project (Fig. 2) shows the improvements in mapping. The area displayed covers the Mee Kwa Mooks area of West Seattle. Improvements include: (1) greatly increased range and quantity of data sources, particularly geotechnical explorations and new field exposures; (2) recognition of greatly expanded landslide areas (outlined dots) that correspond well to areas of historic landsliding (triangles), note the newly identified older landslide area at the edge of the upland; (3) more precise delineation of geologic unit boundaries and recognition of folding of 20,000-year-old beds; (4) inclusion of previously unrecognized geologic units (“Qob” on the lower map); (5) more precise and intuitive rendering of topography; and (6) full digital record of all data sources, mapped contacts, and geologic interpretations.

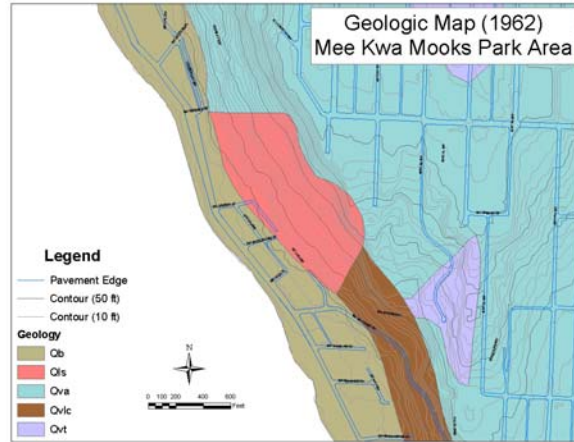


Figure 1. Existing geologic map for the City of Seattle

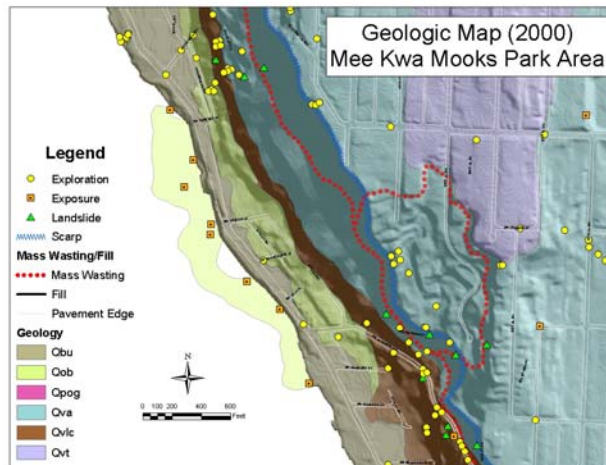


Figure 2. New mapping from the Seattle Geologic Mapping Project

Geologic Framework of Seattle

The near-surface geology of the Puget Lowland strongly influences the pattern of ground motion during earthquakes, groundwater flow paths, slope stability, and bearing strengths. The Lowland is underlain by Eocene to Miocene volcanic and sedimentary rocks deposited as forearc basin fill over older basement rocks. The forearc basin has undergone north-south shortening, resulting in the formation of several large bedrock uplifts and basins, along with smaller folds and faults. A complex, alternating, and incomplete sequence of glacial and nonglacial deposits rests upon this irregular bedrock topography. The depth to bedrock varies from zero to more than 1000 m below the ground surface. Bedrock outcrops in an east-west band across the Lowland at the latitude of south Seattle and also in the foothills and mountains that form the perimeter of the Lowland. Numerous faults and folds, many of Holocene age, have deformed both the bedrock and overlying Quaternary sediments.

The current landscape is largely a result of repeated cycles of glacial scouring and deposition, and recent processes such as landsliding and river action. The north-south ridges and troughs of the Lowland are the result of glacial scouring and subglacial stream erosion. The ridges are generally composed of Pleistocene glacial and interglacial deposits, which are dense and stiff from overriding by multiple advances of 1000-m-thick ice sheets; intervening troughs commonly contain normally consolidated river and lake deposits of the last ice-sheet advance and post-glacial time. Alluvial sediment, predominantly sand and silt, lies many 10's of meters thick in the major river valleys. The steep bluffs and hillsides that border the river valleys, streams, Lake Washington, and the coastline of Puget Sound are mantled with colluvium, which tends to slide during or following periods of heavy precipitation.

Holocene deltas have extended from the mouths of all of the major river valleys into Puget Sound. The most voluminous of the south and central Lowland, those of the Duwamish, Puyallup, and Nisqually rivers, have been fed by sediment from Mt. Rainier. Subsequent commercial and industrial use in both Seattle and Tacoma has required extensive modification of these deltas, principally in the form of fills and retaining structures, that has resulted in extensive port and transportation facilities on loose, saturated soil deposits.