OREGON GEOLOGY

Oregon Department of Geology and Mineral Industries
Volume 63, Number 1, Winter 2001

IN THIS ISSUE:

DOGAMI PUBLICATIONS

Publications are available from: Nature of the Northwest, 800 NE Oregon St. #5, Portland, OR 97232, info@naturenw.org or www.naturenw.org, (503) 872-2750; or from the DOGAMI field offices in Baker City, 1510 Campbell Street, (541) 523-3133, and Grants Pass, 5375 Monument Drive, (541) 476-2496. See also the gray pages at the center of this issue.

Released November 2, 2000:

Relative earthquake hazard map of the Klamath Falls metropolitan area, Oregon, by G.L. Black, Z. Wang, T.J. Wiley, and G.R. Priest. Interpretive Map Series IMS-19; 17 p. text, 1 CD-ROM with map and text data in easily accessible digital form; map scales 1:24,000 for composite relative hazard map, 1:96,000 for three individual hazard maps. $10.

The relative hazard map assigns each map area to one of four relative hazard zones, ranked from the highest hazard (Zone A) to the lowest hazard (Zone D). An advisory committee composed of representatives from local business and the general public provided input and direction for the project.

The assessment of soil behavior (and hence the relative earthquake hazard) is based on geologic mapping and specialized geophysical and geotechnical measurements. These measurements are combined with state-of-practice geotechnical analysis and Geographic Information System (GIS) methodology and tools to produce the final maps.

Released December 8, 2000:

Guidelines for engineering geologic reports and site-specific seismic hazard reports, developed and adopted by the Oregon Board of Geologist Examiners. Open File Report O–00–04, 8 p., $5.

As a service to the technical community, DOGAMI has collaborated with the Oregon Board of Geologist Examiners in publishing these two sets of guidelines.

They are intended to be used as checklists for reports in projects of varying size and complexity. The essential aspects of reports are included, but every project will need a unique set of information. The guidelines for site-specific seismic hazard reports are meant for reports for essential facilities, hazardous facilities, major structures, and special-occupancy structures as provided in Oregon Revised Statutes 455.447(2)(a) and Oregon Administrative Rules 918-460-015. They are not intended to be a complete listing of all the elements of a site-specific seismic hazard report as outlined in Section 2905 of the Oregon Structural Specialty Code. ☐

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 63, NUMBER 1 WINTER 2001

Published quarterly in Winter, Spring, Summer, and Fall by the Oregon Department of Geology and Mineral Industries. (Volumes 1 through 40 were entitled *The Ore Bin*.)

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Periodicals postage paid at Portland, Oregon. Subscription rates: 1 year, $10; 3 years, $22. Single issues, $3.

Address subscription orders, renewals, and changes of address to Oregon Geology, Suite 965, 800 NE Oregon Street # 28, Portland, OR 97232.

POSTMASTER: Send address changes to Oregon Geology, Suite 965, 800 NE Oregon St. # 28, Portland, OR 97232-2162.

Cover photo

Ice Lake and Craig Mountain, just south of Wallowa Lake in the Wallowa Mountains, Oregon's "Switzerland" and geologically one of the most fascinating areas in the state. An August snowfall has blanketed the tarn and horn carved from the Mesozoic granitic rocks of the Wallowa batholith.

In the article beginning on page 13, Robert Carson describes a six-part geologic field trip into the Wallowa Mountains.

The HAZUS-RVS form: A new HAZUS-compatible rapid visual screening form for buildings

by Christine Theodoropoulos, University of Oregon, Eugene, OR 97403-1206, and Yumei Wang, Oregon Department of Geology and Mineral Industries, Portland, OR 97232-2162

ABSTRACT

This paper presents a HAZUS-compatible version of the data collection forms in Federal Emergency Management Agency (FEMA) Publication 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards*. This adaptation of FEMA 154 was designed to facilitate building-inventory data collection in a sidewalk survey of 955 buildings within Klamath County for input into HAZUS risk studies. The new HAZUS-RVS form, which is double sided, has been designed to complement FEMA 154 and can be photocopied for field use. It retains most of the information gathered in the field when FEMA 154 is used and deletes information that is not a necessary part of the field-observation phase of the screening process. In addition, information required by HAZUS, the FEMA software for estimating earthquake losses, has been included. The collected data can be used in comparison studies with existing FEMA 154 data and include additional seismic vulnerability parameters.

INTRODUCTION

This paper provides a modified building-data collection form taken from Federal Emergency Management Agency (FEMA) Publication 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (ATC, 1988). The new form, referred to as the HAZUS-RVS (i.e., rapid visual screening) form, is intended to complement FEMA Publication 154. The paper provides a background on the purpose of collecting building-specific information for use in earthquake risk assessments, describes studies that were conducted during the development of this new HAZUS-RVS form, reviews the contents of the form, provides guidelines that augment the HAZUS-RVS form, and compares a completed FEMA 154 form to a completed HAZUS-RVS form.

The new HAZUS-RVS form, which is double sided and can be photocopied for field use, was developed to facilitate building-inventory data collection for input into HAZUS risk studies. The form retains most of the information gathered in the field on the basis of FEMA 154 and deletes information that is not a necessary part of the field-observation phase of the screening process. In addition, information required by the software HAZUS, the FEMA tool for estimating earthquake losses, has been included (National Institute of Building Sciences, 1997a,b). This adaptation of FEMA 154 was designed to facilitate building-inventory data collection in the State of Oregon for input into HAZUS risk studies as well as for inventory use by others. The data on the new form can be used in comparison studies with FEMA 154 data and include several additional seismic-vulnerability parameters that may be used for mitigation and planning purposes.

BACKGROUND

Why building-data collection is important

Building damage and failure cause the majority of economic and social losses resulting from earthquakes. This is because buildings are the predominant feature of our civilization's environment. In addition to providing for the basic needs of human habitation, buildings house the social institutions and businesses that constitute a functioning society. Some buildings, however, are particularly vulnerable in earthquakes. In order to prepare for future earthquakes and understand how Oregon's building stock is likely to contribute to future earthquake losses, it is necessary to estimate the seismic vulnerability of existing buildings.

HAZUS and its use in Oregon

In 1998, the Oregon Department of Geology and Mineral Industries (DOGAMI) completed preliminary estimates of earthquake-related damage and loss for the State of Oregon. The estimates were obtained with HAZUS97, an earthquake loss estimation software developed by the National Institute of Buildings Sciences (NIBS) and produced by FEMA for use by public agencies (National Institute of Building Sciences, 1997a,b). Earthquake loss estimation tools like HAZUS combine information about geologic hazards with information about buildings and other structures to predict the extent of damage likely to occur in seismic regions. The predicted damage to buildings forms the basis for estimates of numbers of casualties and losses of shelter, of emergency services, and of economic resources.

The results of the preliminary Oregon statewide study indicate that buildings pose serious levels not only of economic risk but of social losses as well. Estimates of total direct economic losses to buildings range from $12 billion for a magnitude 8.5 Cascadia (subduction zone) earthquake up to $32 billion for ground shaking levels assumed by Oregon's "Building Code" (based on a probabilistic earthquake event with a 500-yr return interval). The damage to these buildings was grouped into three state-of-practice damage categories defined by the Applied Technology Council (ATC) (ATC, 1989). As shown in Figure 1 for the Cascadia model, an estimated 885,000 buildings are either not damaged or green-tagged (as defined by ATC), which indicates that a post-earthquake inspection concluded the buildings may be damaged but safe to enter. An estimated 55,000 are yellow-tagged, which allows limited entry but requires permission to enter. An estimated 37,000 are red-tagged, i.e., unsafe to enter (Wang, 1998; Wang and Clark, 1999).

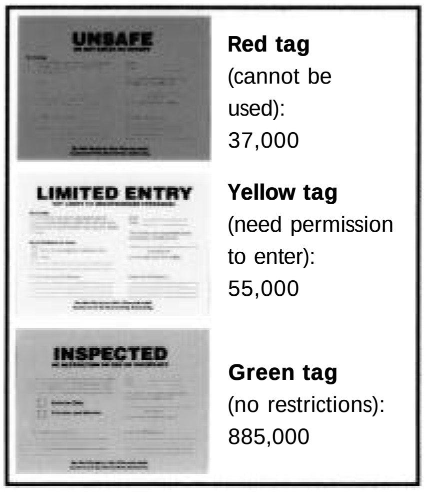

Figure 1. Building damage for Cascadia subduction zone model.

Social losses for the Cascadia and Building Code models include, respectively, about 12,700/29,600 casualties. In addition, estimates include, respectively, about 17,300/47,400 displaced households and 12,400/32,700 short-term shelters needed (Wang, 1998, 1999; Wang and Clark, 1999).

The need for more accurate building data

The above-mentioned estimates of state losses were based on the default building data in HAZUS97. Due to the differences between the default building characteristics in HAZUS and the actual building stock characteristics, this preliminary study underestimates potential damage to buildings and the economic and social losses derived from building performance.

Table 1 illustrates the differences between default values and observed regional construction practices by contrasting data from the default building inventory for government buildings generated by HAZUS97 and the inventory of government buildings from a survey of buildings in the early 1990s in Portland.

Approximately one-fifth of Portland's government buildings included in Table 1 are constructed of wood, considered the safest structural material due to its light weight and inherent flexibility; the remaining four fifths are constructed of other materials. Variations in dates of construction and structural systems affect HAZUS loss estimates, since different damage states are projected for different structural systems of different ages. HAZUS divides building stocks into three age categories; those constructed prior to 1950, between 1950 and 1970, and after 1970. HAZUS also divides building heights into low-, mid-, and high-rise categories. The default values generated by HAZUS97 for the preliminary Oregon loss estimates were based on the assumption that all buildings were low-rise and constructed after 1970. Therefore, the statewide preliminary loss estimate did not include the higher levels of damage expected for Oregon's older buildings. These losses can be particularly significant for communities with unreinforced masonry (URM) buildings, a structural type prone to severe damage and collapse in moderate-level earthquakes. To obtain more realistic projections, future studies for Oregon should be based on a more accurate building inventory informed by actual building data.

Developing a HAZUS-compatible building-data collection form

The HAZUS-RVS form was developed to improve the HAZUS risk evaluation being conducted in the Klamath County Pilot Study (described below). A combination of examining the Portland database and identifying some of the difficulties of using it to generate HAZUS inputs guided the development of the HAZUS building data collection form (Theodoropoulos and Perry, 2000).

The quality of building-inventory data is one of the most critical factors affecting loss estimates, yet comprehensive building inventories containing earthquake vulnerability information about buildings are rarely available. Although many of Oregon's government agencies compile inventory data such as building age, size, value, and others, these inventories do not include many of the parameters

Table 1. Percentages of floor area of low-rise, nonessential government buildings (GOV1) by structural material: Portland survey data versus HAZUS defaults (National Institute of Building Sciences, 1997a,b; Perry and Theodoropoulos, 2000)

	Wood	Steel	Concrete	Precast concrete	Reinforced masonry	Unreinforced masonry
Built before 1950						
Portland Survey	23	8	47	3	11	8
HAZUS default	9	28	46	0	6	11
Built 1950 to 1970						
Portland Survey	20	19	32	9	18	1
HAZUS default	21	13	31	6	29	0
Built after 1970						
Portland Survey	20	22	18	24	17	0
HAZUS default	8	29	34	4	25	0

known to contribute to potential earthquake hazards. An ideal building inventory would include information about the location, size, use, number of occupants, configuration, structural type, and nonstructural earthquake hazards for every building in the study region.

Much of this information can be estimated in the field by trained screeners using FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards*, also known as ATC–21 (or Applied Technology Council Project 21) (ATC, 1988). This quick and relatively affordable sidewalk survey can be conducted by building design professionals and intermediate to advanced university students enrolled in engineering and architecture programs. The FEMA 154 methodology was designed to be used for preliminary identification of potential seismic hazards and cannot be relied upon to produce accurate structural assessments for individual buildings. However, when used to generate data for large numbers of buildings, the method is sufficiently accurate to generate data for loss estimation purposes.

Although it is possible to use FEMA 154 data to prepare building-inventory information for input into HAZUS software, FEMA 154 data differ from HAZUS requirements in three respects:

Occupancy: The 35 occupancy classes used by HAZUS require more detailed information than the eight broad occupancy types asked for by FEMA 154. Although FEMA 154 provides a space for screeners to indicate building use, an examination of databases including this feature shows that screeners' remarks in this field are frequently inconsistent and incomplete, making only a small portion of these databases convertible to HAZUS occupancy format. Translation from FEMA 154 occupancies to general HAZUS occupancy categories is possible, but this will not take full advantage of the HAZUS modeling method (Theodoropoulos and Perry, 2000).

Table 2 illustrates the differences between the FEMA 154 and HAZUS occupancies and illustrates some of the difficulties that can occur in translation when the individual items under general HAZUS groups fall into different FEMA 154 occupancies. The categories of government, public assembly, and emergency services are most problematic because they do not consistently map to general HAZUS classifications.

Structure type: Although most of the structural type designations used by HAZUS match those in FEMA 154, HAZUS structural types include a few variations. FEMA 154 has only one designation for wood structures, whereas HAZUS distinguishes between light wood frame buildings less that 5,000 ft^2 and larger commercial and industrial wood frame buildings. HAZUS also has two categories for reinforced-masonry bearing-wall systems that are more specific about diaphragm materials. In addition, HAZUS identifies mobile homes as a separate structural type.

Number of persons: Studies of a modified version of FEMA 154 data collected for the city of Portland show that screener estimates of numbers of occupants using the "No. Persons" options tend to generate unrealistically high numbers of occupants for a collection of buildings (McCormack and Rad, 1997). A more reliable method of estimating the numbers of people in buildings likely to be affected by earthquakes is needed.

Table 2. Occupancy translations from FEMA 154 to HAZUS classification system

FEMA 154 occupancies	HAZUS occupancies
Residential	RES1: Single family house
	RES2: Mobile home
	RES3: Multi-family
	RES4: Hotel/motel
	RES5: Dormitory
	RES6: Nursing home
Commercial	COM1: Retail store
	COM2: Wholesale/warehouse
	COM3: Personal and repair services
	COM5: Bank
	COM8: Entertainment/restaurant
	COM10: Parking garage
Industrial	IND1: Heavy industry
	IND2: Light industry
	IND3: Food/drug/chem. factory
	IND4: Metal/mineral processing
	IND5: High tech factory
	IND6: Construction
Office	COM4: Prof. service office
	COM7: Medical offices
Government	GOV1: Govt. office
Emergency services	COM6: Hospital
	GOV2/EFFS Fire station
	GOV2/EFPS Police station
	GOV2/EFEO Emergency operations
School	EDU1/EFS1 Primary/high school
	EDU2/EFS2 College/University
Public assembly	COM9: Theater
	REL1: Church
Historic building	No equivalent occupancy
No equivalent occupancy	AGR1: Agricultural uses

DEVELOPMENTAL STUDIES

Three building inventories were conducted in Oregon with the express purpose for use in seismic vulnerability assessments and loss estimations. Two of these surveys, one in Portland and the other in Eugene and Springfield, incorporated FEMA 154 forms for field data collection. The third survey, in Klamath County, was used as a pilot project for the HAZUS-RVS building data collection form.

Lessons learned from the Portland survey

In the early 1990s, FEMA 154 surveys on almost 50,000 buildings were conducted by the City of Portland, the Metro regional government, and Portland State University. The result is the only complete data set of its kind for a metropolitan area in the United States. This exceptional achievement that offers a wealth of information about the seismic vulnerability of a U.S. city represents an important contribution to hazard mitigation research. The Portland building survey includes FEMA 154 data for all buildings within the greater Portland metropolitan plan boundary, with the exception of single-family and duplex residences.

As discussed earlier, the greatest translation problem for HAZUS risk studies lies with the occupancy classes that are much more precisely defined in HAZUS than in FEMA 154. This is important because HAZUS generates tables describing building stock attributes that are organized by occupancy type. Although it is possible to identify some of the HAZUS occupancies in the Portland database from screener comments and building identifiers, the entries in these data columns can be hard to decipher accurately. It is not possible to fully convert the Portland database into a HAZUS format without conducting additional area surveys or making inferences with limited accuracy.

The Klamath County pilot project

In the spring of 1999, faculty and students in the Department of Civil Engineering and Land Surveying at the Oregon Institute of Technology (OIT) completed a sidewalk survey of 955 buildings within Klamath County. DOGAMI sponsored this survey for the purpose of obtaining data about the buildings with highest risk and highest importance in the region for input into HAZUS. Because the purpose of the data collection project was specifically geared toward developing HAZUS input, student screeners recorded field observations on a draft version of the HAZUS-RVS form developed at the University of Oregon and DOGAMI. The resulting database can serve as a model for future field data collection projects. The new form succeeded in facilitating data entry into HAZUS, while it remained comparable with FEMA 154 surveys. Student screeners reported that the form was easy to use, and data entry into HAZUS format from the forms could be completed efficiently. An examination of the OIT data shows a much higher level of consistency and completeness than that found in data compiled for Portland, where FEMA 154 was used. This is due in part to the smaller scale and shorter time frame of the Klamath Falls project. However, the simplification of the sidewalk screening process made possible by the elimination of all FEMA 154 items not directly observable on site may also be a factor.

Results from FEMA field tests

A second test of the new HAZUS-RVS form was conducted at the FEMA-sponsored 1999 National All-Hazards Mitigation Workshop, held in Mount Weather, Virginia. Kenneth Taylor, State Hazard Mitigation Officer and Earthquake Program Manager of the North Carolina Division of Emergency Management led 16 persons in a short course that utilized both the new HAZUS-RVS form and the original FEMA 154 form on four structures. Taylor reported that the participants found the HAZUS-RVS form to be more user friendly than the original form. In addition, the information on the HAZUS-RVS form is more easily integrated into HAZUS than the original form. Following this short course and a review, Taylor recommended that the authors incorporate two additional fields: geo code and site elevation. These new fields were added and are described in the following section.

NEW HAZUS-RVS FORM

Like FEMA 154, this HAZUS-compatible screening procedure can be used to collect information about buildings that are potentially hazardous and may contribute to damage and losses in an earthquake. The HAZUS-RVS form uses the same nontechnical approach found in FEMA 154 that enables trained building design professionals and students to conduct surveys of individual buildings from the sidewalk. The primary purpose of the HAZUS-RVS form is to gather pertinent information about buildings as quickly and accurately as possible. It assists with the evaluation of ordinary residential, commercial, and institutional buildings and is not recommended for structures that are part of military installations, airports, utilities, transportation, communications, bridges, and other infrastructure building components. It is not a substitute for professional evaluations but can provide useful preliminary information about the overall picture of which buildings may be at risk. The data gathered can also be used for loss estimation purposes and are compatible with HAZUS.

The HAZUS-RVS form was created to simplify the process of transferring field information from screening forms into databases in HAZUS format. This eliminates problems caused by differences between HAZUS and FEMA 154 parameters that are time consuming to adjust and compromise data accuracy. Another goal of this project was to streamline the screening process by eliminating all data from FEMA 154 that cannot be collected from the sidewalk. If needed, this additional information can be provided by experts and added to databases more rapidly and more accurately. Tools such as Geographic Information Systems (GIS) and database software can also eliminate the need to manually correlate geologic and building code information for individual buildings or compute the structural scores used to rank buildings according to how hazardous they may be.

The elimination of information not collected in the field made it possible to develop a form that includes a complete listing of all significant parameters by HAZUS label while maintaining a standard-letter sheet size. Explanations of occupancy and structure types appear on the form, making screening faster and more consistent, because screeners do not have to refer to separate sheets for descriptions of uncommon features. It was also possible to add several building attributes not collected by FEMA 154. On the reverse side, a user reference sheet provides guidelines on how to complete the form. These summary guidelines are not all-inclusive and should be augmented by an effective training program for screeners.

Information included on the HAZUS-RVS form

Occupancy classes and occupant numbers: Thirty-seven occupancy classes are listed using the HAZUS four character designations. Brief written definitions enable screeners to interpret each class.

In the Portland study, the FEMA 154 occupant load options were modified to obtain slightly more accurate maximum occupant numbers; but the total number of persons projected by that study far exceeded census estimates for the city and had to be adjusted for loss estimation purposes (McCormack and Rad, 1997). The occupant load tables published in FEMA 154 direct screeners to identify the maximum occupancy rates for buildings using occupant loads derived from building codes. The HAZUS-RVS form takes a different approach. Rather than having screeners estimate maximum occupant rates, screeners indicate the average number of occupants during peak use hours (i.e., evenings for housing, Saturdays for public libraries). In the event that numbers of occupants are difficult to discern from a sidewalk survey, screeners can indicate whether the occupancy rates are likely to be high, average, or low, compared to other buildings in the same occupancy class. This assessment can then be translated, on the basis of building square footage and typical occupancy patterns, into estimates of the number of people likely to be affected in an earthquake.

Structural types: HAZUS combines structural systems and materials with the number of stories to create 26 structure types. To simplify the screeners' task, the form lists the sixteen parameters that designate structure material and adds brief written explanations. Screeners also record the number of stories, so that the data can be entered according to the HAZUS format.

Building configuration: The same five building configuration parameters used in FEMA 154 are listed to identify building geometries known to contribute to earthquake hazards. They include vertical irregularities such as setbacks or the elimination of columns on lower floors, plan irregularities such as re-entrant corners or uncommonly large areas, torsion conditions such as asymmetrically placed cores, soft stories, and short columns. More detail about the nature of the irregularity cited can be provided using sketches and the comment section.

Additional seismic vulnerability parameters: Screeners using FEMA 154 note the presence of large heavy cladding and nonstructural falling hazards. In addition to these, the HAZUS-RVS form includes the following additional seismic vulnerability parameters:

• *Bias:* This is the term used by HAZUS to denote likely design levels by indicating whether structures are built to code, are superior to code, or inferior to code. In the HAZUS-RVS form, screeners respond to two questions to indicate their assessment of the building design level in relation to the codes in force at the time the building was constructed.

• *Condition:* Building maintenance levels can also impact building performance in earthquakes. In the HAZUS-RVS form screeners are asked to indicate whether the building appears to be in poor condition and at greater risk than other well-maintained buildings of its type and age.

• *Visible structural damage:* The purpose of this parameter is to identify building structures that have sustained observable damage from past earthquakes. It was included after an initial rapid visual screening exercise in downtown Klamath Falls (part of the Klamath County Pilot Study) revealed the presence of several buildings damaged in the 1993 Klamath Falls earthquake. Damaged buildings often have less reserve strength and damping capability than undamaged buildings and are more vulnerable to damage in future earthquakes.

• *Retrofitted building:* Retrofitted buildings are less hazardous than unretrofitted buildings of the same construction type and age. Although screeners may not always be able to detect whether a building has been retrofitted, there are several retrofit construction methods such as the introduction of braced frames or wall-to-floor diaphragm anchors that can be observed.

• *Vacant building:* This parameter has an effect on the person number count and occupancy class designation.

• *Sloped site or fill slope:* Buildings constructed on sloping sites can be more vulnerable than buildings on flat sites. This is also true for buildings constructed on flat surfaces formed by cut-and-fill regrading. The supporting soil can become unstable during an earthquake. In addition, buildings on sloping sides often have vertical irregularities in the zone where the building meets the ground. Although topographic maps can be used to obtain general slope of grade conditions for an area, they are generally available at a regional scale only and cannot be relied upon to provide accurate information about actual slope conditions at the foundations of a particular building. On large lots with variable slope, field observation is needed to determine where the building is sited with respect to topographical features. The HAZUS-RVS form requires screeners to indicate if the building is on a sloped site or fill slope.

• *Geo code:* This describes the coordinates (e.g., latitude and longitude) of the building location. This can be determined with hand-held field GPS units or from topographic or other maps. These data can be integrated into GIS systems and GIS-based software, including HAZUS.

• *Site elevation:* This is the lowest elevation of the site and vertical datum. These data can be used for flood, storm, and tsunami hazards.

• *Building height:* FEMA 154 requires the number of stories. The HAZUS-RVS form requires the number of stories and the building height. Building height is a significant seismic response parameter but cannot be accurately determined from the number of stories due to variations in story height.

• *Building footprint area:* In addition to the total floor area of the building, the HAZUS-RVS form prompts screeners to estimate the size of the building footprint. This gives some indication of the building massing and the size of building diaphragms.

• *Building orientation:* By including a north arrow on plan sketches, screeners can record the orientation of buildings. Although building orientation is not commonly considered in the seismic design of buildings, estimation of damage states for loss estimates, or post-earthquake damage assessments, predictive models based on scenario earthquakes may evaluate the directional effects of anticipated ground motion on buildings in the near future.

Information deleted from the FEMA 154 form

Several items in the FEMA 154 form have been removed from the HAZUS-RVS form. Information that can be obtained in the pre- and post-screening phases of compiling building inventories has been deleted. This includes parameters such as building code benchmark years and Uniform Building Code (UBC) soil types that are likely to apply to all of the buildings in a survey.

In addition, the structural scoring matrix used to rank the relative risk of buildings based on their structural type has been deleted. In addition to the fact that scoring is an activity not directly related to field observation, the authors suspect that the relative risk of different structural types may change as more data about building performance are obtained. Furthermore, regional construction practices, codes, and procedures may affect the relative risks. Lastly, many persons, in particular nontechnical persons, view the scoring system with concern because they believe a building's score could cause potential political and economic repercussions to owners, tenants, and communities. By eliminating the scoring system and focusing on descriptive data only, inventory collection projects may experience less resistance from building owners.

Samples of completed data collection forms

Figures 2 and 3 compare the use of the FEMA 154 form to the HAZUS-RVS form. The building illustrated in the examples is the City of Eugene Public Library.

The Public Library in Eugene, Oregon, was constructed in 1959 on the corner of 13th Avenue and Olive Street in the downtown area. It is a two-story building with a basement. All three levels contain library spaces accessible to the public. It is constructed of reinforced concrete and uses shear walls for lateral resistance. The second story is smaller than the ground floor and set back from the building perimeter, creating a vertical irregularity in the building massing. Although classified as a concrete structure for the purpose of loss estimation, this is actually a building of mixed construction: the upper roof is framed in steel. The two walls fronting the streets have windows, which creates a configuration that can make a building susceptible to torsion forces during an earthquake. The cantilevered canopy may present a falling hazard. The Eugene Public Library has outgrown this present building, and a new building is planned to replace it. In the meantime, the library is heavily used and has evening and Sunday hours. The building is a typical example of a mid-century modern community library and may be regarded as an historic structure in the near future.

Figures 4a and 4b are blank samples of the new HAZUS-RVS form that can be used for reproduction of the front and back pages of the form.

SCREENER TRAINING REQUIREMENTS

The qualifications of screeners and an effective screener training program are critical to ensuring that data collected in the field are as accurate as possible. Although FEMA 154 states that the rapid visual screening methodology can be conducted by trained laypersons, data collection projects in Oregon have been most effective when screeners had professional or educational experience in building design, construction, or assessment. The most challenging task for screeners with limited access to buildings is to determine the correct structural type. For important buildings, such as essential facilities housing emergency response functions, survey projects should budget additional time for screeners to consult facilities representatives or construction documents to accurately determine unknown structural types. A training program that focuses on local construction

(Continued on page 12)

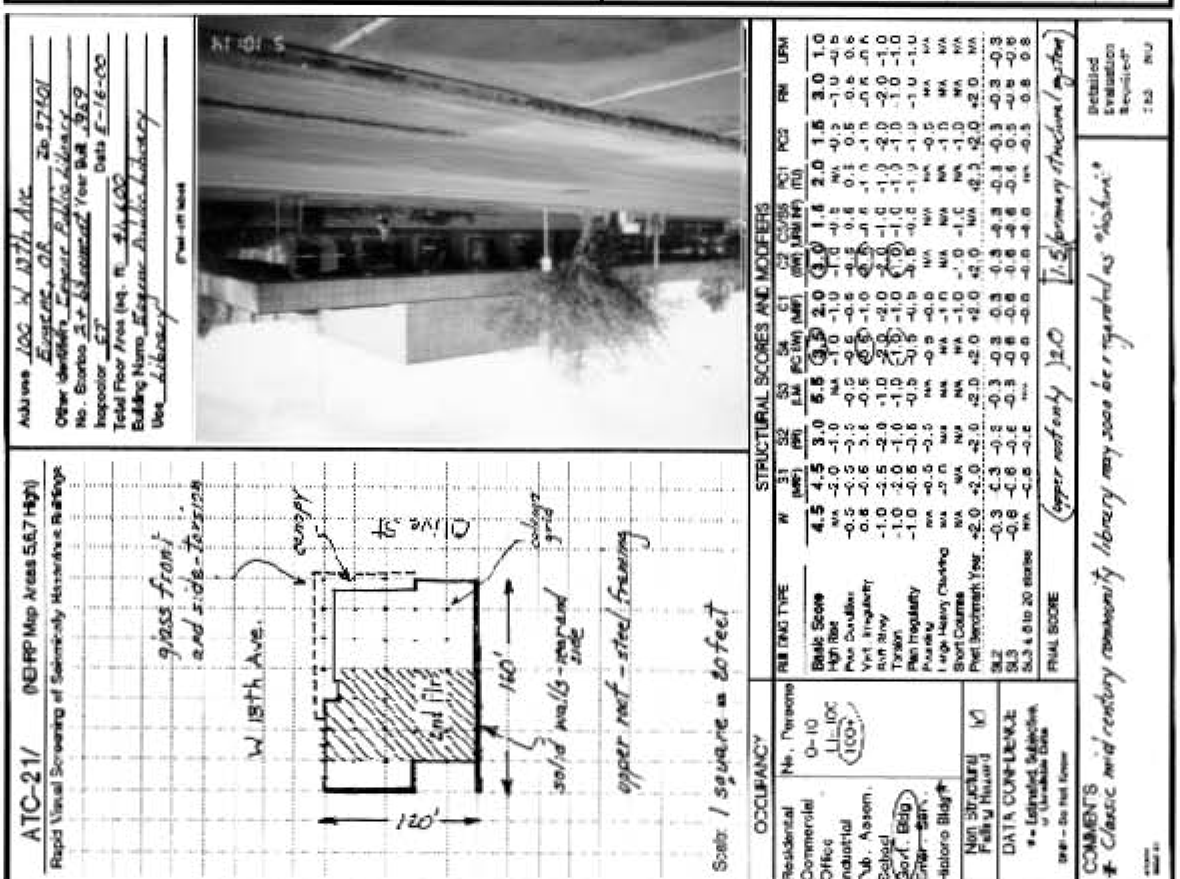

Figure 2. Completed FEMA 154 form for the Eugene Public Library.

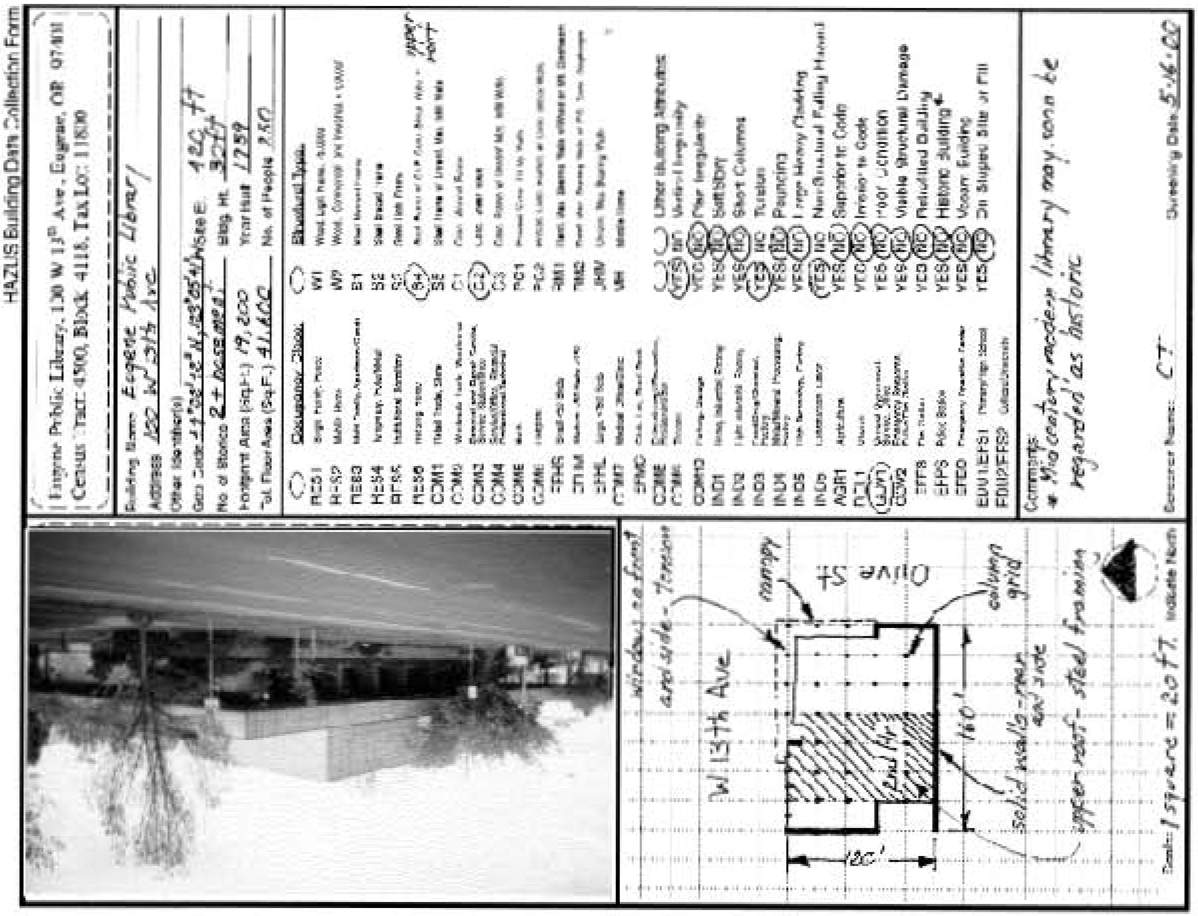

Figure 3. Completed HAZUS-RVS form for the Eugene Public Library.

Following pages (10 and 11): Figures 4a and b. Blank new HAZUS-RVS form, front and back pages, for reproduction purposes.

PHOTO

Place Pre-printed Tracking Label Here
(Can include City, Census Tract, Tax Lot, Zip Code...)

Building Name ____________________

Address ____________________

Other Identifier(s) ____________________

Geo Code ____________ Site El. ____________

No. of Stories ____________ Bldg. Ht. ____________

Footprint Area (ft²) ____________ Year Built ____________

Total Floor Area (ft²) ____________ No. of People ____________

OCCUPANCY CLASS

RES1	Single Family, House
RES2	Mobile Home
RES3	Multi-Family, Apartment/Condo
RES4	Temporary, Hotel/Motel
RES5	Institutional Dormitory
RES6	Nursing Home
COM1	Retail Trade, Store
COM2	Wholesale Trade, Warehouse
COM3	Personal/Repair Service
COM4	Professional Service/Office
COM5	Bank
COM6	Hospital
EFHS	Small <50 Beds
EFHM	Medium >50 Beds <150
EFHL	Large >150 Beds
COM7	Medical Office/Clinic
EFMC	Clinic, Lab, Blood Bank
COM8	Entertainment/Restaurant/Rec
COM9	Theater
COM10	Parking, Garage
IND1	Heavy Industrial, Factory
IND2	Light Industrial, Factory
IND3	Food/Drug/Chemical Factory
IND4	Metal/Mineral Processing Factory
IND5	High Technology, Factory
IND6	Construction, Office
AGR1	Agriculture
REL1	Church
GOV1	Government Service/Office
GOV2	Emergency Response
EFFS	Fire Station
EFPS	Police Station
EFEO	Emergency Operation Center
EDU1 / EFS1	Primary or High School
EDU2 / EFS2	College or University

STRUCTURAL TYPE

W1	Wood, Light Frame, <5,000sf
W2	Wood, Commercial/Industrial, > 5,000sf
S1	Steel Moment Frame
S2	Steel Braced Frame
S3	Steel Light Frame
S4	Steel Frame w/ C.I.P. Conc. Shear Walls
S5	Steel Frame w/ Unreinf. Mas. Infill Walls
C1	Conc. Moment Frame
C2	Conc. Shear Walls
C3	Conc. Frame w/ Unreinf. Mas. Infill Walls
PC1	Precast Conc. Tilt-Up Walls
PC2	Precast Conc. Frames w/ Conc. Shear Walls
RM1	Reinf. Mas. Bearing Walls w/Wood or Mtl. Diaphragm
RM2	Reinf. Mas. Bearing Walls w/ P.C. Conc. Diaphragm
URM	Unreinf. Mas. Bearing Walls
MH	Mobile Home

OTHER BUILDING ATTRIBUTES

YES	NO	Vertical Irregularity
YES	NO	Plan Irregularity
YES	NO	Soft Story
YES	NO	Short Columns
YES	NO	Torsion
YES	NO	Pounding
YES	NO	Large Heavy Cladding
YES	NO	Non-Structural Falling Hazard
YES	NO	Superior to Code
YES	NO	Inferior to Code
YES	NO	Poor Condition
YES	NO	Visible Structural Damage
YES	NO	Retrofitted Building
YES	NO	Historic Building
YES	NO	Vacant Building
YES	NO	On Sloped Site or Fill

SKETCH

Scale

Indicate North

COMMENTS:

Screener Name ____________ Screening Date ____________

PHOTOGRAPHY TIPS

A wide angle lens is recommended.

Photograph from a sufficient distance to include the whole building if possible.

Select a view that will aid in building identification such as the front facade and one adjacent side.

The view selected can be used to clarify a building attribute. For complex buildings, additional photos are an option.

If the identification of building age or structural type is uncertain, select a view that will assist a consulting expert in making a determination.

Avoid obstructions by cars, trees, utility lines when possible.

The quality and durability of instant photos are often less than other photographic methods but they save time and can be attached to the screening form directly in the field. When taking photographs that must be developed or downloaded off-site it is important to maintain an accurate photo log keyed to screening forms.

When possible, the camera should be held level and parallel to the horizon. An adjustment may be necessary due to building height or accessibility.

Plan the times of your screening route to avoid pointing the camera in the direction of the sun or strong sunlit facades.

SKETCHING TIPS

Use sharpened # 2 pencils or a mechanical pencil and a good quality eraser.

Make clean, dark, reproducible lines. Use gridlines as guides to make straight, orthogonal lines.

Include a plan of the building footprint shown approximately to scale. Use gridlines to assist in representing approximate proportions and as a scaling tool. (i.e. one square = 30 feet)

Include approximate overall plan dimensions.

Show location of adjacent streets and buildings.

Place a north arrow in the circle provided.

Annotate the plan to identify building features such as the configuration of upper stories or location of visible structural damage.

Do not add other sketches such as elevations unless they are essential to record important information that will not be visible on the photograph.

Sketches can also be prepared from construction documents, aerial photographs or maps during the pre-field phase of the screening process and verified in the field.

GENERAL BUILDING INFORMATION

Address and Geo Code: Always include an address or exact location. Do not use geo code in lieu of address.

Year Built: If year built is unknown, estimate date or decade based on building style or context.

Year Built, No. of Stories, and Height: If more than one date, no. of stories or height, list from greatest to least according to size of building area affected (i.e. a 3 story building with a small 4th floor penthouse would be listed under No. of Stories as "3,4")

No. of People: Estimate the number of people likely to be in the building at typical peak-use times. The following maximum occupancy loads (in square feet per person) are provided for reference. Note that these loads will usually overestimate typical peak-use numbers of people.

residential	100-300	assembly	10+
commercial	50-200	school	50-100
office	100-200	government	100-200
industrial	200-500	emergency	100

BUILDING USE & SEISMIC PARAMETERS

Occupancy Class: For mixed use buildings circle all primary uses. Do not include secondary uses that occupy relatively small building areas such as a retail pharmacy within a hospital. Note that "EF" designations should be used for post-earthquake essential facilities only.

Structural Type: For definitions see HAZUS Users' Manual Appendix B. If the structural type cannot be determined, circle all likely types and note uncertainty in comments section. If more than one structural type is present circle all that apply. In comments or sketch explain the distribution of structural type in the building

Other Building Attributes:

VERTICAL IRREGULARITY - Includes story setbacks, vertical geometric irregularities of the lateral force resisting system such as discontinuous shear walls, mass irregularities, weak stories.

PLAN IRREGULARITY - Includes re-entrant corners, discontinuous diaphragms, non-parallel systems, out-of-plane offsets, & large footprints.

SOFT STORY - Can be caused by a tall first floor, a relatively open and flexible first floor or a floor with fewer or more flexible lateral load resisting elements.

SHORT COLUMNS - Columns that are shorter than the majority of columns carrying lateral loads often found at building perimeter and sloping sites.

TORSION - A plan irregularity in which the lateral load resisting system is not concentric with the building mass.

POUNDING - Caused when adjacent buildings "pound" against one another.

LARGE HEAVY CLADDING - Such as precast concrete panels.

NON-STRUCTURAL FALLING HAZARD Parapets, awnings, signage, etc.

SUPERIOR TO CODE - Likely to exceed code in force at time of construction.

INFERIOR TO CODE - Likely to not meet code in force at time of construction.

POOR CONDITION - Evidence of maintenance problems that may affect integrity of building structure.

VISIBLE STRUCTURAL DAMAGE Cracks, out-of-plumb columns and other signs of damage to structure in a post-earthquake area.

RETROFITTED BUILDING - Evidence of seismic retrofit installations such as braces.

HISTORIC BUILDING - buildings of historic significance at least 50 years of age.

VACANT BUILDING - Not occupied.

ON SLOPED SITE OR FILL - Slopes greater than 10 degrees.

SUGGESTED COMMENTS

Clarify any multiple entries for single data items. Screener uncertainty or evidence of mixed age, use or structure types?

Identify original building use if different from present use.

Note observable surface soils conditions such as: bedrock outcrops and topographical features, i.e. adjacency to a body of water.

Further explanations of building attributes, or other seismically significant information such as seismic design code used.

THESIS ABSTRACT

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that in our opinion are of general interest to our readers.

Effects of urbanization on streamflow in three basins in the Pacific Northwest, by Julie L. Clark (M.S., Portland State University, 1999), 136 p.

Three basins in the Puget Sound-Willamette Valley lowland area of western Washington and Oregon were analyzed to see if there were significant posturbanization differences in storm peak flows, storm volumes, and ratios of those variables to antecedent precipitation indices spanning 15 to 120 days.

Criteria for inclusion of basins included a flow record duration of at least 50 years and minimal disruption by impoundment or diversion. Basins selected included the Tualatin River (1,807 km^2) and Johnson Creek (68 km^2), both near Portland, Oregon; and the Newaukum River (397 km^2) near Centralia, Washington. A nonurbanized basin, the Luckiamute River (614 km^2) near McMinnville, Oregon, was used as a reference.

Peak flow rates higher than a one-year recurrence interval (RI) were used. The data set for each basin was broken into early and late periods. Linear regression, F and t tests, ANOVAs, and Spearman-Conley nonparametric tests were performed on the entire data set and on data subsets characterized by season (November-December and January-February) and by size (RI 1-1.9 years and RI 2–10 years).

Precipitation was unchanged between the early and late periods, suggesting changes in flows were due to urbanization, not climate.

The nonurbanized Luckiamute basin showed no changes in streamflow characteristics. Even after urbanization, the Tualatin showed no changes in streamflow characteristics. The Newaukum, however, had higher peaks (21 percent increase), storm volumes (10 percent increase), and (peak/volume) to antecedent precipitation ratios (18–22 percent increases). John-

(Continued on page 35)

(Continued from page 8)

practices is preferred over generic training. In addition, building professionals with long-term experience in the survey region can serve as consultants on survey projects. Their experience often enables them to make an accurate determination of a structural type from the field photographs attached to the forms.

ACKNOWLEDGMENTS

Special thanks to Carol Hasenberg of Portland State University for her work on the studies, her use of the forms in a draft state, and the helpful review of this paper. We thank Dawn Woods, a former University of Oregon (UO) Department of Architecture graduate student, who was instrumental in developing the layout and content of early versions of the HAZUS-RVS form; also Karen Chan, a UO undergraduate, who worked on the design of the document, reviewed drafts, and contributed to the development of the instructions to screeners. Thanks to Andrew Schmidt of DOGAMI for his thoughtful review comments on the paper.

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Where the Rockies meet the Columbia Plateau: Geologic field trip from the Walla Walla Valley to the Wallowa Mountains, Oregon

by R.J. Carson, Department of Geology, Whitman College, Walla Walla, Washington 99362, carsonrj@whitman.edu

This field trip guide was prepared for the Keck Geology Consortium Symposium, supported by the W.M. Keck Foundation and held at Whitman College in April 2000. —*ed.*

INTRODUCTION

The magnificent scenery of northeastern Oregon is largely the result of an exciting geologic history with similarities to both the Rockies to the east and the Columbia Plateau to the west. Exotic volcanic and sedimentary rocks originating far away in the ancestral Pacific Ocean were accreted to North America late in the Mesozoic. Accretion-related intrusion, metamorphism, and uplift in places like the Wallowa Mountains are similar to those of the Idaho batholith to the east. Northeastern Oregon was then eroded to near sea level before widespread volcanism occurred throughout the Tertiary. The Miocene Columbia River basalts are the principal constituent of a diverse assortment of felsic and mafic volcanic (and volcaniclastic) rocks emplaced from the Eocene through the Pliocene. The whole package of rocks, from the accreted terranes to the young volcanic rocks, was folded and faulted in the late Cenozoic, creating many small mountain uplifts. These range from the glaciated Wallowa Mountains cored by granitic rocks to the larger Blue Mountains anticlinal ridge composed almost entirely of basalt flows. The rocks visible on this field trip are listed in the composite stratigraphic column shown in Figure 1.

The term "Blue Mountains" has two meanings. In the broad sense, it describes a mountainous section of the Columbia Plateau (Fenneman, 1931; Thornbury, 1965; Hunt, 1974), including the Strawberry, Elkhorn, Wallowa, and Blue Mountains in Oregon and Washington and the Seven Devils Mountains east of Hells Canyon in Idaho. It is also a geographically more restrictive term referring only to the anticlinal ridge which stretches from Clarkston, Washington, to north-central Oregon. In this guide, "Blue Mountains" refers to only the northeast-southwest-trending anticline of basalt flows, with Walla Walla and Milton-Freewater to the northwest and La Grande and Elgin to the southeast.

Our journey begins in the Walla Walla Valley which straddles the Washington-Oregon state line. With its tributaries, the Walla Walla River originates in the Blue Mountains at elevations over 5,000 ft and empties into the Columbia River (elevation 340 ft) just north of the Wallula Gap. The Walla Walla Valley's borders are as follows:

North: The Palouse Hills of Quaternary loess

East and southeast: The Blue Mountains

South: The Horse Heaven Hills, an anticlinal ridge of Miocene basalt (and the Olympic-Wallowa lineament)

West: "Nine-Mile Hill"—a basaltic high with the Pasco Basin to the west

The field trip stops are shown on the sketch map of northeastern Oregon (Figure 2). From Milton-Freewater (in the southeastern corner of the Walla Walla Valley) the route goes south across the Olympic-Wallowa lineament, the east end of the Horse Heaven Hills, and the narrow valley of the Umatilla River.

Note

Take this trip in good summer weather. Some roads will be closed in winter; some may be impassable just because of bad weather conditions. It is always a good idea to gather weather information before such a trip. Not all roads are paved, but all are negotiable with normal passenger vehicles in fair weather.

Be aware of traffic conditions. Some roads may be heavily used by log or gravel trucks, and since you are in tourist country, you will also find many recreational vehicles that could cause problems.

At many stops, no specific directions are given as to parking. You will have to judge from the given situation how to handle this safely. At all times, drive and stop with due caution!

Stop 15 requires a National Forest Service (NSF) trail head parking permit now called Northwest Forest Pass (day, $5; year, $30). This pass can be obtained online at www.naturenw.org (phone 1-800-270-7504), at any NSF office, or from any of over 300 independent vendors throughout Oregon and Washington.

Interstate Highway 84 takes us across the anticlinal uplift of the Blue Mountains. Soon after we reach the Grande Ronde River, flowing along the southeast flank of the Blue

Mountains, we can see a cutoff incised meander at Perry.

At La Grande, we enter the graben of the Grande Ronde Valley across which the Grande Ronde River wanders. This graben is bordered by the Blue Mountains to the northwest, the Wallowa Mountains to the east, and the Elkhorn Mountains to the south. We follow the Grande Ronde River downstream, leaving the main graben and entering a smaller one in which Elgin lies. At Elgin we turn eastward and cross an upland before descending to Minam, where the Minam River joins the Wallowa River.

From Milton-Freewater to Perry, all the rocks are middle Miocene basalt flows of the Columbia River Basalt Group. Exposures of rocks other than Miocene Columbia River basalts are rare in the Blue Mountains but include Mesozoic terrane rocks in the upper Tucannon River drainage at the Washington end of the uplift to the northeast, and granitic rocks at Battle Mountain Summit toward the southwest end.

From Perry to Minam, the volcanic rocks vary more in composition, texture, and age. For example, mapping by Carson and students of Whitman College in the late 1980s revealed felsic, pumiceous, and volcaniclastic rocks in addition to the basalt flows. Dating by Ferns and Madin of the Oregon Department of Geology and Mineral Industries in the late 1990s yielded ages as young as Pliocene for the volcanic rocks (Ferns and others, in preparation). These rocks lie on top of the Columbia River basalts and are much like the Powder River volcanic rocks (Hooper and Swanson, 1990).

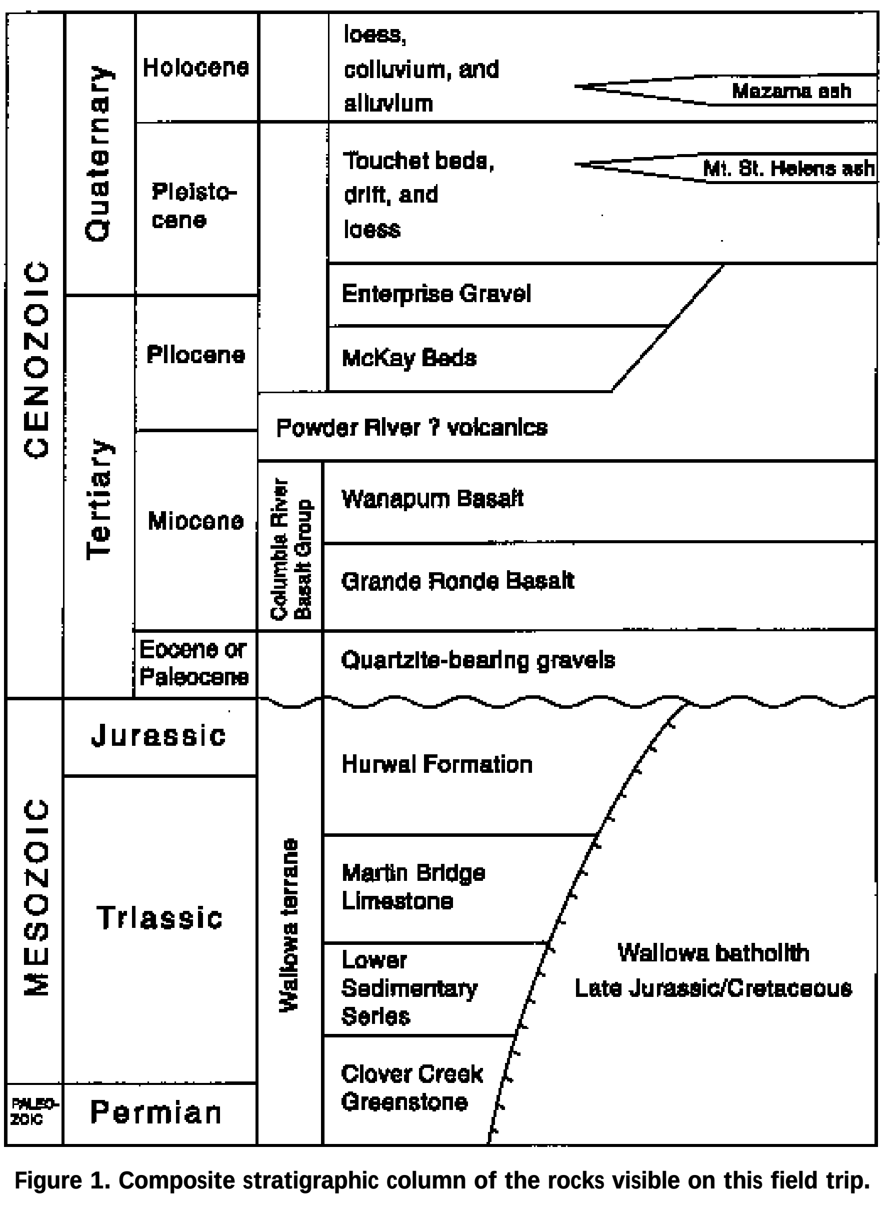

Figure 1. Composite stratigraphic column of the rocks visible on this field trip.

As we follow the Wallowa River upstream from Minam to Wallowa, the canyon ends as we cross the Olympic-Wallowa lineament again. We enter the ancient homeland of the Nez Perce Indians, a fertile valley at the north edge of the Wallowa Mountains. The borders of this highest range in northeastern Oregon are as follows:

Northeast: The Olympic-Wallowa lineament, and the Joseph Upland, a plateau of basalt that stretches north to the Grande Ronde River

East: Hells Canyon of the Snake River, with Idaho's Seven Devils Mountains on the other side

South: The Powder River

Southwest: Fault-bounded Baker Valley and, farther southwest, the Elkhorn Mountains, mostly Mesozoic accreted terrane and granitic intrusives

West: The Grande Ronde Valley

Northwest: The Grande Ronde River

The Olympic-Wallowa lineament, the Wallowa River, and Oregon Highway 82 lead southeast through the towns of Wallowa, Lostine, Enterprise, and Joseph to Wallowa Lake. The combination of two deep merging glacial troughs to the south and two huge merging lateral moraines to the north make Wallowa Lake one of the most scenic places in North America. Within a few kilometers of the lake a variety of Mesozoic igneous, metamorphic, and sedimentary rocks are found, in a landscape shaped by many late Cenozoic glacial, periglacial, fluvial, and mass-wasting processes.

The general geology of northeast-

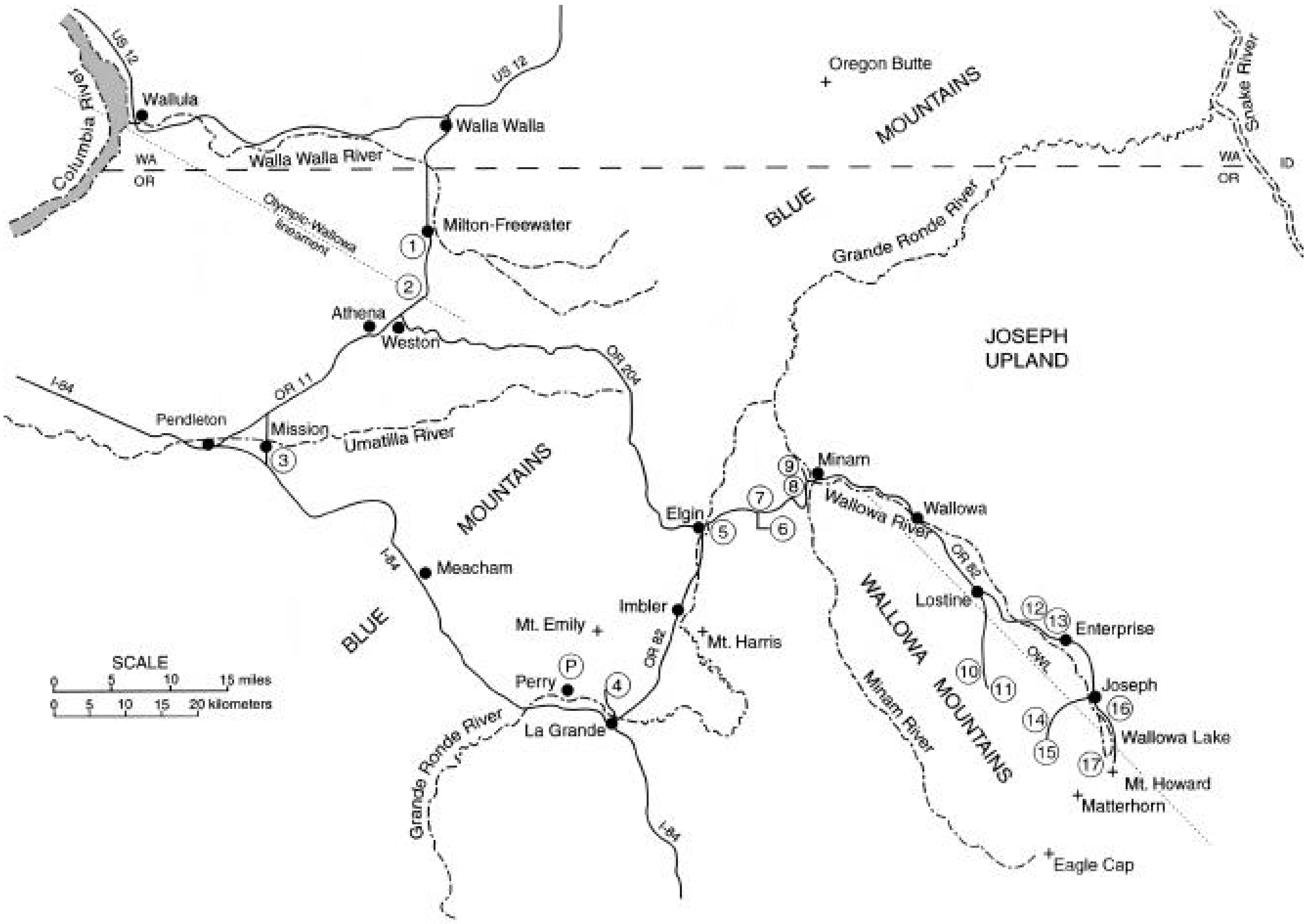

Figure 2. Sketch map of the field trip region, showing stops as circled numbers. Circled "P" = optional stop.

ern Oregon and adjacent areas is addressed in the following publications:

FURTHER READING

Less technical

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ACKNOWLEDGMENTS

This field trip guide was prepared for the Keck Geology Consortium Symposium, supported by the W.M. Keck Foundation and held at Whitman College in April 2000. I am indebted to Patti Moss for work on the manuscript and to Todd Shearer for help with the illustrations. Whitman College provided support for field work in connection with preparation of this guide. Molly Gerber and Matt Clausen, Whitman College students, and Jay Van Tassell, Professor of Geology at Eastern Oregon University, were enthusiastic companions during field work. I also thank John Winter, Pat Spencer, Kevin Pogue, and Carolyn Nielsen for editing the manuscript.

ROAD LOG

Part 1 — Milton-Freewater to La Grande

Miles

0.0 *Proceed south along Oregon Highway 11 from the Milton-Freewater City Hall (west side of South Main Street between SW 7th and SW 8th Streets).*
Elevation here is 1,033 ft. Had you lived here between about 15,300 and 12,700 years ago, you would have been inundated by at least one of 40 or more floods. British Columbia's Cordilleran ice sheet advanced south into Idaho, blocking the Clark Fork River. The ice dam created glacial Lake Missoula (Pardee, 1910), which covered western Montana with 2,500 km^3 (600 mi^3) of water (Waitt, 1985). The dam repeatedly failed, sending gigantic jökulhlaups (glacial outburst floods) west across northern Idaho, south across eastern Washington, and then west along the Columbia River (Waitt, 1980). The major bottleneck for these floods was Wallula Gap, which the Columbia River cut across the Horse Heaven Hills about 50 km (31 mi) west of Milton-Freewater. Wallula Gap formed a hydraulic dam to the jökulhlaups causing the water to rise to an elevation above 1,200 ft and back up into the Walla Walla Valley to the east of Walla Walla and the south of Milton-Freewater. Imagine being under 60 m of water here!
Had you been here on July 15, 1936, you would have felt Oregon's greatest historic earthquake. The quake, which occurred at 11:05 p.m., broke many chimneys; several houses were moved off their foundations; and many ground cracks appeared, aligned west-northwest (Brown, 1937), parallel to the Olympic-Wallowa lineament. The quake's intensity was VII+, its magnitude was about 6.1; and the total damage was $100,000 in 1936 dollars (Wong and Bott, 1995).

0.4 Stop 1 — Alluvium on Wanapum Basalt
Exposure on west side of South Main Street at the south end of Milton-Freewater (elevation 1,100 ft). The bedrock is the Miocene Wanapum Basalt of the Columbia River Basalt Group. Above the basalt lies alluvium of the old Walla Walla River—the modern Walla Walla River is less than 0.5 km (0.3 mi) to the east. Above these gravels you see fine-grained sediment of three possible origins: (1) Quaternary loess, (2) late Pleistocene Touchet Beds, and/or (3) overbank deposits of the ancient Walla Walla River. Touchet Beds (slackwater deposits of the Missoula floods) are possible here because flood height at Wallula Gap on the Columbia River (near the mouth of the Walla Walla River) was 1,200 ft (Waitt, 1994). The exposure is coincident with a northeast-facing scarp that is part of the Olympic-Wallowa lineament (OWL). Here the scarp is partly due to erosion by the Walla Walla River. The OWL (Raisz, 1945) is a northwest-trending feature that stretches from the Strait of Juan de Fuca (between Vancouver Island and the Olympic Peninsula) to the Wallowa Mountains. This is the southeastern end of a portion of the OWL called the Cle Elum-Wallula deformed zone (Reidel and Lindsey, 1991).

Continue south (uphill) on Oregon Highway 11.
Thin loess at the top of the hill is underlain by the Miocene Saddle Mountain Basalt of the Columbia River Basalt Group.

4.2 Begin series of road cuts, mostly in the Wanapum Basalt of the Columbia River Basalt Group.

5.4 Stop 2 — Fault through Wanapum Basalt
(Best exposed on northwest side of highway). This stop is between two intermittent streams (Dry Creek and Little Dry Creek) and before the intersection with Winn Road. The west-southwest-dipping "Dry Creek Fault" is associated with the OWL. The basalt has been ground to breccia and gouge.

Continue south on Highway 11.

6.9 *Continue straight (on Highway 11) at junction of Oregon Highways 11 and 204* (elevation 1,877 ft).
Highway 204 leads 42 mi over the Blue Mountains to Elgin. This is an alternate and shorter route of return from Wallowa Lake. The Horse Heaven Hills anticline stretches west-northwest from here; this anticline is the easternmost of the Yakima Fold Belt (Tolan and Reidel, 1989).

9.9 *Continue straight (on Highway 11) at junction with east-west road to Weston and Athena.*

15.1 *Continue straight (on Highway 11) at junction with road west to Adams.*
Oregon Highway 11 is following the valley of Wildhorse Creek, which flows southwest to the Umatilla River.

22.9 *Junction with Moens Road. Turn left (south) on Moens Road.*
To the south is the huge Blue Mountain anticline.

23.9 Going down the hill, you see an exposure of the Pliocene McKay beds (see Stop 3). The valley of the Umatilla River is cut in the Wanapum Basalt of the Columbia River Basalt Group.

24.9 *Cross Umatilla River.*
(Note osprey nest near southwest corner of the bridge). The Umatilla River flows west and joins the Columbia River in the Umatilla Basin.

25.4 *Mission* (elevation 1,215 ft) on the Umatilla Indian Reservation.

Continue south and up the hill.

26.0 Stop 3 — Gravels of the McKay beds
The type locality of the McKay beds is at McKay Reservoir just

(Continued on page 21)

PLEASE SEND US YOUR PHOTOS

Since we have started printing color pictures on the front cover of *Oregon Geology*, we are finding ourselves woefully short of good color photographs showing geologic motifs in Oregon.

We also want to make recommendations for scenery well worth looking at in a new series of black-and-white photos on the back cover of *Oregon Geology*. For that, too, your contributions are invited.

Good glossy prints or transparencies will be the best "hard copy," while digital versions are best in TIFF or EPS format, on the PC or Mac platform.

If you have any photos that you would like to share with other readers of this magazine, please send them to us (Editor, *Oregon Geology*, 800 NE Oregon Street, Portland, OR 97232-2162) with information for a caption. If they are used, the printing and credit to you and a one-year free subscription to *Oregon Geology* is all the compensation we can offer. If you wish to have us return your materials, please include a self-addressed envelope.

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Oregon Geology is designed to reach a wide spectrum of readers interested in the various apsects of the geology and mineral industry of Oregon. Color photos for publication on the front cover are highly welcome, as are letters or notes in response to materials published in the magazine.

Two copies of the manuscript should be submitted, one paper copy and one digital copy. All digital elements of the manuscript, such as text, figures, and tables should be submitted as separate files, not as incorporated, e.g., in a word processor product for a paper version. Hard-copy graphics should be camera ready; photographs should be glossies. All illustrations should be clearly marked. Captions should be placed together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) Bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Include names of reviewers in the acknowledgments.

Conclusions and opinions presented in articles are those of the authors and are not necessarily endorsed by the Oregon Department of Geology and Mineral Industries.

Authors will receive 20 complimentary copies of the issue containing their contribution.

Manuscripts, letters, notices, and photographs should be sent to Klaus Neuendorf, Editor, at the Portland office (address in masthead on first inside page).

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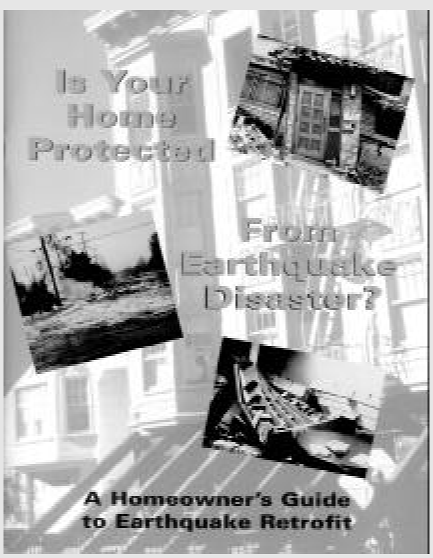

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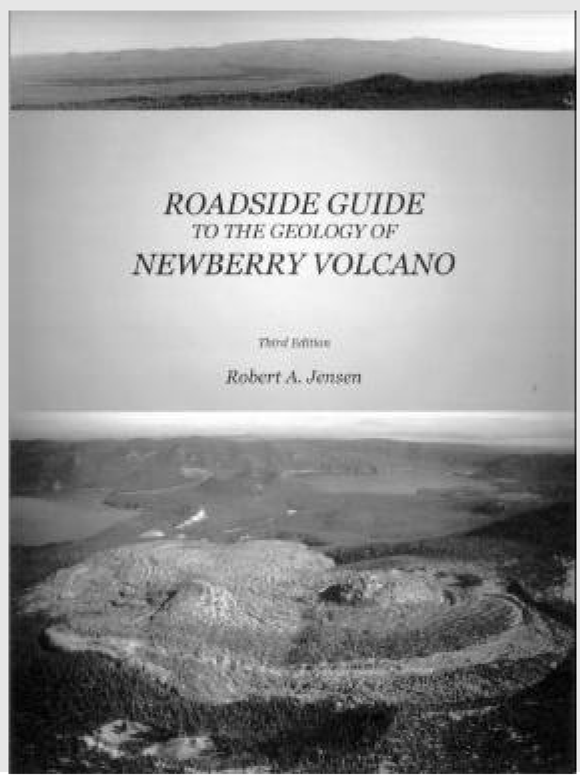

(Continued from page 16)
south of Pendleton; there the gravels include sand and silt lenses and are interpreted as a fanglomerate (Hogenson, 1964). The McKay beds are Pliocene, according to mammal fossils (Shotwell, 1956); they may correlate with the Dalles Formation to the west (Newcomb, 1966). Most of the cobbles are derived from erosion of the Columbia River basalt in the Blue Mountains.

27.5 *Turn left (southeast) after Wildhorse Casino* (elevation 1,400 ft)*, enter Interstate 84 (at unmarked Exit 216) and follow it toward La Grande.*

29.8 *Start up Blue Mountain anticline.* The elevation increases from less than 2,000 ft to more than 3,000 ft in a few miles and eventually reaches more than 4,000 ft at the top of the anticline. Most of the road cuts are in the Grande Ronde Basalt of the Columbia River Basalt Group, but on top of the Blue Mountains you can see some Wanapum Basalt.

40.4 *Rest area on Interstate 84 at Deadman Pass* (elevation 3,615 ft).

45.4 *Emigrant Spring State Park* (elevation 3,800 ft).

52.9 *"Summit" of Blue Mountains* (elevation 4,193 ft).
This is approximately the axis of the Blue Mountain anticline (Walker, 1973).

64.1 *Hilgard Junction State Park at exit 252 of Interstate 84.*
Here the Grande Ronde River at mile 170 (170 river miles above its confluence with the Snake River) is at an elevation of 3,000 ft. It is incised about 500 ft into the Grande Ronde Basalt. From here downstream to La Grande and upstream to Red Bridge Wayside, the Grande Ronde River lies close to the axis of the Grande Ronde syncline (Ferns and others, in preparation). The western part of the state park is on a terrace about 38 ft above the meandering river. The strath terrace has gravels over basalt.

66.5 Starting at milepost 255 on Interstate 84, you find exposures of Mazama ash on the south bank of the Grande Ronde River (see Stop 11). The ash is interpreted as filling gullies that existed during the huge eruption at Crater Lake about 6,845 years ago.

67.7 *Cross Grande Ronde River.*

67.8 Optional Stop P — Cutoff incised meander.
Take Exit 256 to Perry on Interstate 84. The stop is about 1 mi east at the Perry cutoff incised meander (Barrash and others, 1980) which is visible at mile 68.8 on this road log. From the exit ramp bear left and cross over Interstate 84. Bear left again and turn right at Frontage Road. Proceed southeast through the western portion of the community of Perry and cross the bridge to the north side of the Grande Ronde River. Turn left under the railroad tracks to the eastern portion of the community of Perry.
The core of the cutoff incised meander (Figure 3) is a hill of Grande Ronde basalt rising about 200 ft above the abandoned river course, which drops from 2,903 ft to below 2,880 ft. The elevation of the Grande Ronde River here is about 2,870 ft; the canyon rises to 4,650 ft (Mahoghany Mountain) on the north and to about 3,900 ft on the south. The canyon walls are mostly cut in Grande Ronde Basalt, but younger volcanic rocks (Powder River equivalents?) are present at the top of the canyon on both sides. A landslide occurred on the steep slope on the northeast side of the cutoff incised meander (Barrash and others, 1980). Three more cutoff incised meanders lie along the lower Grande Ronde River (Gerber and others, 2000).
Perry was the site of a sawmill and log-catch dam at the turn of the century. Each day, five "splash dams" along the upper Grande Ronde River were opened to flush logs downstream to the mill (Gildemeister, 1999).

Return to Interstate Highway 84. (Road-log mileage continues as if this optional stop was not visited.)

68.8 *Cross Grande Ronde River.* View of Perry cutoff incised meander to north.

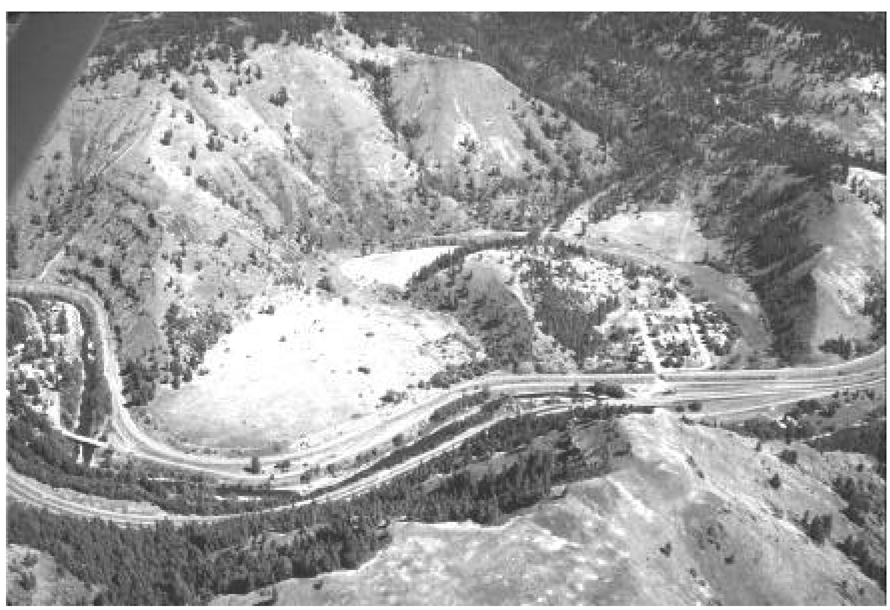

Figure 3. Cutoff incised meander of Grande Ronde River at Perry. To the left of the town of Perry lies the abandoned core of the meander. Behind Perry rises the toe of an ancient landslide. Grande Ronde River flows from left (west) to right.

70.8 Lateritic paleosol between flows of the Grande Ronde Basalt, between bridges over the Grande Ronde River.

Take exit 259 to La Grande on U.S. Highway 30 (sign to Elgin and Wallowa Lake via Oregon Highway 82).

71.0 *Cross Grande Ronde River.* Enter Grande Ronde Valley in La Grande Basin (see Stop 4).

71.5 *Enter La Grande.*

72.0 *Bear left onto Adams Avenue.*

72.3 *At the stoplight at Second Street* (elevation 2,790 ft)*, turn left (north) toward Fairgrounds.*

72.6 *Overpass at railroad tracks.*

73.2 *Overpass at Interstate Highway 84 and the Grande Ronde River; then bear left.*

73.4 *Bear right at Union County Fairgrounds.*

73.5 *Go straight at stop sign. Second Street becomes Black Hawk Trail Lane.*
The toe of a large landslide is straight ahead (see Stop 4).

73.6 *Black Hawk Trail Lane turns left (west)*
and then passes the toe of a smaller landslide on the right (north).

74.3 *At base of hill, Black Hawk Trail lane turns right (north) uphill and becomes Fox Hill Road.*
Note shallow road cuts of fine-grained sediments at base of hill. On the hillside are the Union County Landfill and quarries/gravel pits in the Grande Ronde Basalt. What are the potential problems of a landfill here?

75.3 Stop 4 — Overview of landslide and Grande Ronde Valley/ La Grande Basin

This stop is at a slight left turn in Fox Hill Road, at an elevation of 3,630 ft. Walk east 50 m (160 ft) to the top of the scarp.

The La Grande Basin (Figure 4) is surrounded mostly by Grande Ronde Basalt but partly by younger volcanic rocks (especially to the west) (Barrash and others, 1980). It is bordered by a few large down-to-the-west normal faults on the northeast and many smaller down-to-the-east normal faults on the southwest (Tolan and Reidel, 1989). Truncated spurs are particularly prominent along the northeastern side of the basin. The Grande Ronde River has a very low gradient across the basin; there are meanders, oxbows, and meander scars. A major shortcut was created in the 1870s with the excavation of the State Ditch, which is approximately 7.2 km (4.5 mi) long and bypasses about 63 km (39 mi) of the river, from river mile 154 to river mile 115. Fromwiller and Van Tassel (1999) summarized the development of the Grande Ronde Valley. It has been interpreted as an extensional graben (a northern extremity of the Basin and Range) or as a pull-apart basin related to motion along the Olympic-Wallowa lineament. The initial formation was

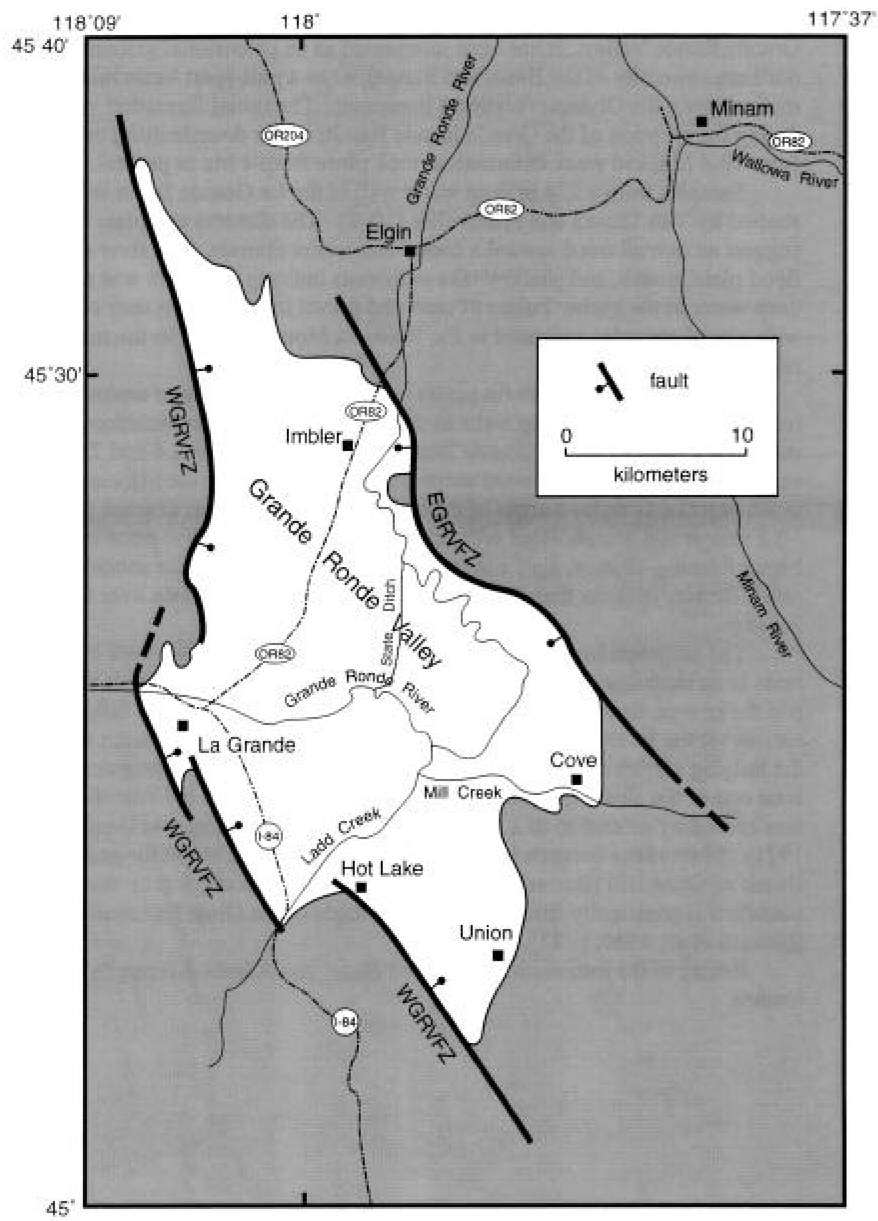

Figure 4. Map of Grande Ronde Valley/La Grande Basin, showing the graben bordered by the West Grand Ronde Valley fault zone (WGRVFZ) and the East Grand Ronde Valley fault zone (EGRVFZ). After Personius (1998).

during the eruption of the Grande Ronde Basalt; major downfaulting occurred from 10 to 4 Ma, and weak deformation took place from 4 Ma to the present.

Samples from a 224-m-deep (735 ft) water well in the La Grande Basin were studied by Fromwiller and Van Tassel (1999). The diatoms and plant fossils suggest an overall trend toward a cooler and wetter climate. River channel, flood plain, marsh, and shallow-lake sediments indicate that the basin was never filled with deep water. Pulses of sand and gravel into the basin may correlate with glacial episodes indicated in the Wallowa Mountains and in the marine record.

Van Tassell and others (2000) used $^{40}Ar/^{39}Ar$ dating of tephra samples recovered from several deep wells to determine sediment accumulation and subsidence rates of the La Grande Basin. Ash layers dated at 2.6 and 7.5 Ma suggest the following: (1) sediment accumulation began during the Miocene; (2) the southwest (La Grande) margin of the basin has subsided at an average rate of ~0.2 mm/yr and accumulated sediment at a rate of ~0.05 mm/yr since the basin began forming ~9 m.y. ago; and (3) over the past 2.6 m.y., the southwest basin margin has subsided at a rate 0.02 mm/yr faster than the northeast (Cove) side of the basin.

The landslide here may have originated as a slump, but the bulk of the mass is an earthflow (Figure 5). The top of the concave main scarp is at 4,020 ft, and the convex tip of the earthflow is at 2,860 ft. The top half of the failure is narrow: at the level of this stop it is about 200 m (650 ft) wide; the maximum width of the bulging earthflow toe is more than 900 m (3,000 ft). The earthflow is hummocky; at least one of the closed depressions contains a small pond. It is likely that failure was caused by saturation of a fine-grained interbed (Schlicker and Deacon, 1971). Most of the bedrock here is Grande Ronde Basalt, but at the scarp it is the Basalt of Glass Hill (Barrash and others, 1980). "Rock debris making up the earthflow is principally from flows and interbeds of the Glass Hill sequence" (Barrash and others, 1980, p. 23).

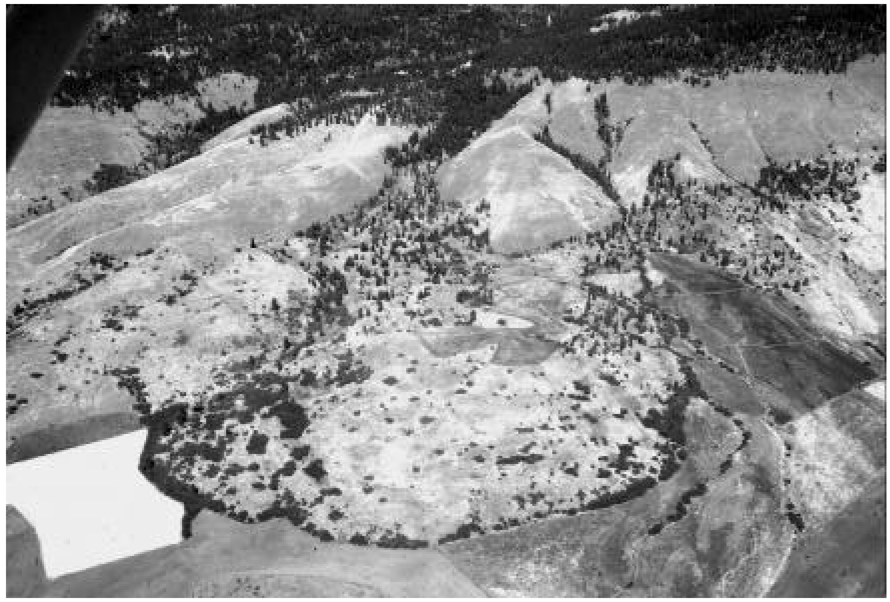

Figure 5. Landslide north of La Grande discussed at Stop 4. The mass-wasting event originated as a small slump at the top of the slope and spread out as an earthflow on the floor of the Grande Ronde Valley. The city landfill is along the road on the ridge to the left (west).

Return to the intersection of Second Street and Adams Avenue in La Grande.

Part 2 — La Grande to Cricket Flat

0.0 *Go east on Adams Avenue (U.S. Highway 30) from the intersection with Second Street.*

0.2 *At stoplight, bear right on Adams Avenue through downtown La Grande* (elevation 2,787 ft).

A block farther northeast are the Union Pacific Railroad yards. Underground fuel lines between underground storage tanks and the main line leaked diesel fuel from the mid-1950s until the early 1980s. The diesel fuel contaminated groundwater and soil. In the 1980s, monitoring and recovery operations were performed. Pumps recovered 44,680 gallons of diesel oil that was floating on the water table (The Observer, La Grande, Oregon, January 11, 1996). As of the mid-1990s, concerns still persisted about health and property values near the rail yards. Soil in and around the rail yards remained wet with diesel oil (Michael Anderson, Oregon Department of Environmental Quality, written communication, 1995). Downtown commercial properties had their market values lowered. The City of La Grande and downtown property owners sued the railroad in 1996 and agreed to a settlement in 1997. The lawsuit cited consequences from the contamination including diminished property values, loss of groundwater use for decades, health and safety claims, and blight and damage to surface water and potential drinking water (The Observer, La Grande, Oregon, January 11, 1996). The out-of-court settlement included payment by the Union Pacific Railroad to the City of La Grande and more than 40 private litigants of more than $13 million and the company's agreement to clean up property and wells (The Observer, La Grande, Oregon, November 26, 1997). A representative of the Union Pacific Railroad stated that the cleanup would take less than 15 years (The Observer, La Grande, Oregon, February 25, 1998). It was then discovered that the plume of contamination may be larger than earlier indicated, and 40 more property owners planned to sue the Union Pacific Railroad (The Observer, La Grande, Oregon, April 16, 1999).

0.7 *Turn left (northeast) on Oregon Highway 82 (Island Avenue) toward Elgin and Wallowa Lake.* Just to the southwest, the campus of Eastern Oregon University sits on a terrace about 33 ft (10 m) above downtown La Grande. Jay Van Tassell obtained a radiocarbon age of 15,280 ± 180 years from a mammoth tooth in loess on top of the terrace gravels (Van Tassel, oral communication, 2000).

1.7 *Underpass beneath Interstate Highway 84.*

2.4 *Enter Island City.*
This town was an island prior to the 1964 flood, which also damaged La Grande (Van Tassell, oral communication, 1999).

3.2 *Turn left (north) at stop light (sign to Imbler, Elgin, and Enterprise).*

3.3 *Cross Grande Ronde River and bear right, continuing on Oregon Highway 82.*
Between here and Imbler are good views of the fault scarps and truncated spurs to the east. The high point, Mount Harris (elevation 5,357 ft) is a volcanic complex with a summit composed of rhyodacite; some of the lava flows of this volcano are dark andesites (Mark Ferns and Vicki McConnell, Oregon Department of Geology and Mineral Industries, oral communications, 1999).

12.8 *Enter Imbler* (elevation 2,718 ft), which is situated on top of Sand Ridge.

16.1 *Leave Grande Ronde Valley.*
For the next 3 mi or so, Oregon Highway 82 is just west of the Grande Ronde River. The river is confined between Pumpkin Ridge to the west and a ridge extending north from Mount Harris to the east.
An earthflow happened here in February 1996 during a rain-on-snow event that caused floods and landslides throughout the Pacific Northwest (Carson and others, 1998). The earthflow is part of an older landslide complex moving from Pumpkin Ridge toward the Grande Ronde River. The 1996 earthflow dropped the highway, and its toe covered the railroad below. The Oregon State Highway Department installed horizontal drains in the upper part of the slide and placed rocks at its base (Jay Van Tassell, oral communication, 2000). The total cost of cleanup and stabilization of the 1996 landslide was $147,668.

17.9 *Cross Grande Ronde River. Enter Indian Valley, the Elgin Basin.*
The Elgin Basin may be a small example of an extensional graben or pull-apart basin (see Stop 4).

19.3 *Cross Grande Ronde River (again!).*

19.6 *Enter Elgin.*

20.1 *Intersection of Oregon Highways 204 and 82.*
Oregon Highway 204 goes over the Blue Mountains and is a shorter route to Milton-Freewater than the one through La Grande.

20.2 *Oregon Highway 82 turns right (east) in downtown Elgin* (elevation 2,670 ft).

20.5 *Cross Grande Ronde River (last time!).*
The southern of two Twin Coves landslides straight ahead.

21.0 Stop 5 — Overview of Indian Valley/Elgin Basin.
Stop near Oregon Highway 82 milepost 21.
The *Geologic Map of Oregon* by Walker and MacLeod (1991) shows almost all Columbia River Basalt Group from here to Cricket Flat. However, pyroclastic units and at least one andesite flow have been found in the area (Swanson and others, 1981; Carson and others, 1989).
Several northwest-trending faults are located in the vicinity of Elgin. Jones Butte, about 4.4 km (2.7 mi) northwest of this stop, is a volcanic dome complex exposed by erosion. With an age of only 2 Ma, it is the youngest known volcanic rock of this area (Mark Ferns, Oregon Department of Geology and Mineral Industries, written communication, 1999). The cliff that is visible 6.5 km (4 mi) north-northwest of this stop, a landslide scarp known as Rockwall, is an andesite flow tentatively assigned to the Miocene-Pliocene Powder River volcanic rocks and informally named here the andesite of Rockwall (Figure 6). The andesite of Rockwall overlies tuff; this creates a huge area of landslide terrain between the Rockwall and the Grande Ronde River.
A similar situation exists at the Twin Coves: Basalt capping the hill to the east overlies felsic tuff exposed in the road cut here. Each of the Twin Coves is a landslide, with a slump at the top and an earthflow below.
To the northwest, on the west side of the Grande Ronde River, a railroad cut exposes 10 m (30 ft) of sandy gravels containing basalt cobbles. There appears to be a buried soil or overbank deposits 2–3 m (6–10 ft) below the top. The gravels are interpreted to be fluvial, with some hyperconcentrated flow events. They were mapped as Quaternary by Walker (1979).

21.2 The northern of the Twin Cove landslides to the east.

21.3 Tuff exposed in failing road cut.

Figure 6. Columns of the andesite of Rockwall discussed at Stop 5. Rockwall is a landslide scarp in an andesite flow 6 km (3.7 mi) north of Elgin. The andesite is tentatively assigned to the Miocene-Pliocene Powder River volcanic rocks.

24.8 Tuff in road cuts.

25.4 *Turn right (south) onto Hindman Road.*

27.4 *Turn left (east) onto the south part of Roulet Loop.*

28.1 Stop 6 — Pumicite
Small road cut of pumicite on south side of hill. A lava flow caps the hilltop (elevation 3,570 ft). This consolidated pumice is exposed here and there for almost a mile to the east. Buttes of pumicite occur north of the Roulet Loop just 0.5 mi to the east. The pumicite is probably related to the Powder River volcanic rocks. No source for the pumice clasts is known, but a vent is assumed to be close. According to Mark Ferns (Oregon Department of Geology and Mineral Industries, written communication, 1999), similar pyroclastics are found along Indian Creek to the south, and Ferns observes that they may make a useful "stratigraphic marker between the top of the Grande Ronde [Basalt] and the base of the olivine basalt flows."
Return to the intersection of Hindman Road and Oregon Highway 82 and park here for Stop 7.

Part 3 — Cricket Flat to Minam

0.0 Stop 7 — Volcanic rocks
Exposure on Oregon Highway 82 just east of Hindman Road. From the intersection, walk east along the north side of Oregon Highway 82 (being very careful of traffic!). The ditch and road cut contain tuff with lithic clasts up to 40 cm across. The clasts are mostly from Tertiary lava flows, but some are from Mesozoic rocks and quartzites of unknown age (probably Proterozoic or Paleozoic). Quartzite-rich alluvium and scattered boulders and cobbles are known from a wide area of northeastern Oregon. Where in place, they overlie Mesozoic rocks and are below Tertiary volcanic rocks (Allen, 1991; Carson and others, 1995; Trafton, 1999). The tuff also contains abundant pumice clasts of various sizes and scattered obsidian Apache tears up to 3 cm across. Also found are rare fossils (imprints) of leaves of deciduous trees and fragments of partially carbonized wood. The tuff, probably related to the Powder River volcanic rocks, may be a lahar but is more likely to be a pyroclastic flow deposit. Wood was charred where the pyroclastic flow was hotter, closer to the vent, but here the temperature had cooled enough so that leaves did not burn. The fragments of Mesozoic rocks may have been ripped out of the conduit, but some are rounded, suggesting that they were incorporated into the pyroclastic flow as it crossed stream gravels.
At the east end of the exposure, the tuff is capped by a paleosol with vertical prisms (Figure 7).

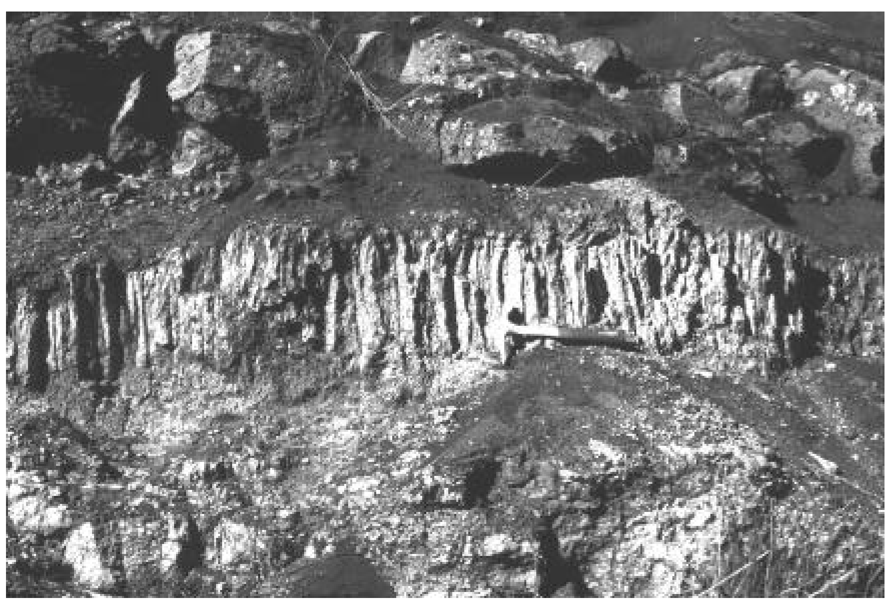

Figure 7. Volcanic rocks at Cricket Flat, in road cut discussed at Stop 7. From bottom to top, we see the top of a pyroclastic flow deposit, a soil and/or bake zone with vertical prisms, and the base of an olivine basalt flow.

The feature may be related to baking by the overlying basalt flow. Hooper and Swanson make brief reference to the geology of this area: "The Cricket Flat [olivine basalt] flow is locally underlain by a silicic ash-flow tuff" (Hooper and Swanson, 1990, p. 89).

Return to vehicle and continue east on Oregon Highway 82.
Between here and Minam Summit the patterned ground (Figure 8) is similar to that on the tops of Washington's Yakima Hills and Oregon's Deschutes-Umatilla Plateau. The silt mounds are about 1 m (3 ft) high and 10 m (30 ft) in diameter. They appear to be remnants of a loess cover over the youngest basalt flow (Figure 8).

1.0 Quarry in basalt flow.

3.4 *Minam Summit* (elevation 3,660 ft).

4.4 Beginning of an almost continuous exposure of Grande Ronde Basalt of the Columbia River Basalt Group. To the east, the Minam River has cut through about 300 m (1,000 ft) of these lava flows.

5.8 Stop 8 — Grande Ronde Basalt in canyon of Minam River
Park on the east side of the road just north of a "bridge" over the west side of the canyon.
Note the small landslide scars on the east side of the canyon. Some of the mass-wasting occurred during a rain-on-snow event in February, 1996 (Carson and others, 1998).
The basalt flows exhibit columnar jointing, flowtop breccias, and vesicles of various sizes. Exposures of red tuffaceous paleosols between lava flows are common in these road cuts. Enough time passed between eruptions for lateritic soils to develop in the subtropical climate. The climate interpretation is substantiated by the species of trees at Ginkgo Petrified Forest State Park in central Washington (Carson and others, 1987).

Figure 8. Patterned ground on Cricket Flat west of Minam Summit. The silt mounds, about 1 m (3 ft) high and 10 m (30 ft) in diameter, overlie basalt. Photo by Pat Spencer.

In places, spiracles are found: cones of fractured basalt extending from a breccia at the base of a lava flow perhaps to its top. A spiracle is probably created by a steam blast derived from superheating in a local pocket of water-saturated sediments (Mackin, 1961).

Walk uphill (south) along the west side of the highway
to a horizontal 1-m-diameter (3-ft) cylindrical hole in the cliff. This is the largest of several lava tree molds with bark impressions.

6.9 Beginning of an area of unstable slope—unstable because of the presence of a fault zone and a thick paleosol. The Oregon State Highway Department has put concrete and drains at the weak paleosol, visible where the concrete has fallen.

7.6 *Union-Wallowa County line.*

7.9 *Stream gage on Minam River.*

8.2 *Minam* (elevation 2,537 ft). *Turn left (north), off Highway 82, toward Minam State Park along the west bank of the Wallowa River.*

9.7 Stop 9 — Columbia River basalt dike at Minam State Park
Park your vehicle just ahead at the state park; walk back to the dike.
The constriction in the Wallowa River (the water turns into a rapid here, at some discharges) is due to the presence of a north-striking dike of Grande Ronde Basalt which cuts through slightly older Grande Ronde Basalt flows.

Return south to the junction with Oregon Highway 82 at Minam.

Part 4 — Minam to Lostine

0.0 *Junction of Oregon Highway 82 with road to Minam State Park. Go east toward Wallowa Valley.*

0.1 *Bridge over Wallowa River and its tributary, the Minam River.*
Like the Minam River, the Wallowa River is incised about 300 m (1,000 ft) into the Grande Ronde Basalt.

2.8 *Wallowa Wayside State Park.*

5.7 Stone stripes straight ahead on west-facing slope of canyon wall (north side of Wallowa River). Stone stripes are a form of sorted patterned ground in which stripes of coarse rock fragments occur between stripes of finer material (Washburn, 1956).

6.0 *Rest area.*

8.3 Leave canyon of Wallowa River. Cross Olympic-Wallowa lineament. Enter Wallowa Valley. The Olympic-Wallowa lineament strikes southeast, with the Wallowa Mountains uplifted to the southwest, and the Joseph Upland, capped with Grande Ronde Basalt, located to the northeast of the Wallowa Valley.

12.1 *Cross Wallowa River.*

12.5 *Enter Wallowa* (elevation 2,948 ft).

16.0 The right lateral moraine of the valley glacier that occupied the glacial trough along the Lostine River is straight ahead. An alluvial fan complex is at the base of the Wallowa Mountains to the south.

20.6 *Enter Lostine* (elevation 3,363 ft).

20.9 *Go straight (south) toward "Lostine River campgrounds," leaving Oregon Highway 82 where it veers left (east) toward Enterprise.*

21.9 Drop from outwash terrace and onto floodplain of Lostine River. Outwash gravels are exposed here.

22.8 Climb up from floodplain to lowest terrace.

23.1 Climb up onto prominent outwash terrace. Boulders to the east are associated with right lateral moraines of the Lostine glacier. The Lostine valley glacier (Figure 9), 35 km (22 mi) long when it was at its maximum about 15,000–20,000 years ago, was the longest in the Wallowa Mountains, originating near Eagle Cap (elevation 9,595 ft) in the center of the range and descending to an elevation of 3,380 ft (Allen, 1975).

24.1 Road goes through gap in largest end moraine; smaller terminal and recessional moraines are to the north and south.

25.1 Small end moraine with dirt road on top loops westward across valley floor. The lake just to the south is impounded with a low, moraine-looking, artificial levee or earthen dam.

26.0 Miocene Grande Ronde Basalt crops out immediately to the east; yet straight ahead, high on the eastern wall of the glacial trough, is Triassic Martin Bridge Limestone (limestone and marble). These outcrops must be separated by a major fault along the Olympic-Wallowa lineament.

26.9 The quarry to the east is in the Triassic Lower Sedimentary Series (see Stop 10), which here consists of weakly metamorphosed shale, sandstone, and black limestone.

Do not enter the quarry without permission!

27.5 *Cross Lostine River.*

28.4 Stop 10 — Triassic Lower Sedimentary Series
This unit is mostly marine shale and sandstone that have been altered to hornfels and schist near the Wallowa batholith (Smith and Allen, 1941). Here the foliation, which is parallel to the bedding, dips east. The thickness of the Lower Sedimentary Series is 0–600 m (0–2,000 ft). It rests conformably on top of the Clover Creek Greenstone and is separated from the overlying Martin Bridge Limestone (Martin Bridge formation of Smith and Allen, 1941) by an unconformity. Look high on the west side of the glacial trough to see the Martin Bridge Limestone and, above that, the Columbia River basalts.

28.5 Pleistocene till in road cut.

28.8 *Enter Wallowa-Whitman National Forest.*

28.9 Folded rocks of the Lower Sedimentary Series.

29.3 Stop 11 — Mesozoic Wallowa batholith at Pole Bridge
The old wooden bridge over the Lostine River has been replaced by a concrete bridge. The batholith was intruded during the Late Jurassic and Early Cretaceous, between 160 and 120 million years ago (Orr and others, 1992). The Wallowa batholith is a composite

Figure 9. View north from Eagle Cap down the Lostine glacial trough. In the foreground are snowfields and Holocene moraines at the base of Eagle Cap. Granitic bedrock in the middle ground is part of the Wallowa batholith.

intrusion that commenced with many small gabbroic bodies, continued with four major units of zoned tonalite-granodiorite, and terminated with many small felsic masses (Taubeneck, 1987). Above the northwest end of the bridge the granodiorite has been smoothed by the overriding Lostine glacier.

The gorge just upstream is due, at least in part, to erosion by glacial meltwater and the Lostine River. Look at the east wall of the glacial trough. At bridge level you see the Triassic Lower Sedimentary Series. Above it lies the Triassic Martin Bridge Limestone (limestone and marble). Conformably overlying the Martin Bridge Limestone is the Late Triassic-Early Jurassic Hurwal Formation, composed of shale, sandstone, slate, and hornfels up to 1,500 m (~4,900 ft) thick (Baldwin, 1981). These Triassic and Jurassic strata are part of the Wallowa terrane (Vallier, 1998). Fossils of mollusks, corals, and ichthyosaurs in the Martin Bridge Limestone and the Hurwal Formation are similar to fossils found in rocks across southern Eurasia (Orr and others, 1992).

Walk 100 m (300 ft) along the road to the southeast and a road cut in a small, steep, postglacial alluvial fan.

Near the top you see a large lens of Mazama ash (Figure 10). Mount Mazama underwent a catastrophic eruption and caldera-forming collapse that led to today's Crater Lake 6,845 ± 50 ^{14}C yr B.P. (Bacon, 1983), or 5,677 ± 150 B.C. (Zdanowicz and others, 1999). The original tephra fall here was perhaps 10–20 cm thick (Farren and Carson, 1998), but it was eroded from the uplands and concentrated in this alluvial fan.

Return north to the junction with Oregon Highway 82 in Lostine.

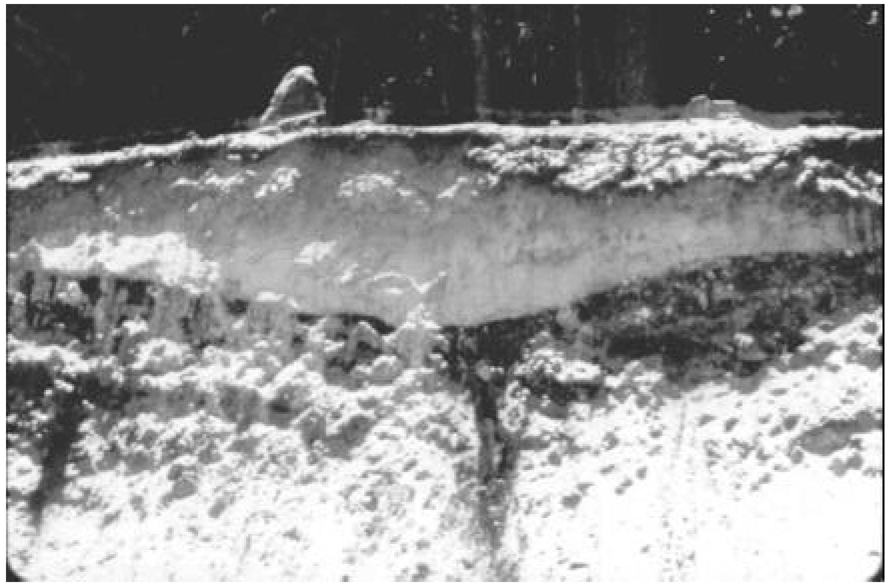

Figure 10. Lens of Mazama ash near top of aluvial fan near Pole Bridge over the Lostine River, as seen at Stop 10. The Mazama ash was erupted about 6,800 years ago, in the eruption that produced Crater Lake.

Part 5 — Lostine to Joseph

0.0 *Junction of Lostine River Road with Oregon Highway 82. Go east on Oregon Highway 82 toward Enterprise.*

2.2 Road cuts in Grande Ronde Basalt of the Columbia River Basalt Group on the east side of Wades Point. Note the prominent red lateritic paleosol just above road level.

5.0 *Cross the Wallowa River.*

7.9 Stop 12 — Grande Ronde Basalt

This stop is near the middle of 1.6 mi of road cuts in the Grande Ronde Basalt (about 16 m.y. old) of the Columbia River Basalt Group. To the west of a fault (dipping steeply west) is a single thick flow of weathered basalt. To the east of the fault are dozens of thin flows including black glassy basalt and red scoriaceous basalt (Figure 11). Four small, west-dipping dikes may be associated with a larger vent (not visible in the road cut) that was the source of the east-dipping thin flows. These thin flows may be the eastern part of a cone. To the east of the small dikes, an abrupt steepening of the thin flows may be due to collapse accompanied by rafting away of a portion of the cone by a thick lava flow exposed in the east part of the road cut.

Columbia River Basalt Group flows are also on top of Sheep Ridge, about 7 km (4.4 mi) to the southwest at an elevation of more than 7,600 ft. Sheep Ridge is on the upthrown side of the Wallowa Fault (part of the Olympic-Wallowa lineament). The maximum displacement along the Wallowa Fault is 2–2.4 km (1.2–1.5 mi) (Taubeneck, 1997).

9.3 *Enter Enterprise* (elevation 3,757 ft).

In the road cut just ahead on the left you see Enterprise Gravel (see Stop 13).

9.5 Stop 13 — East end of type locality for Enterprise Gravel

Visible to the southwest are (1) the modern course of the Wallowa River; (2) Alder Slope, a complex of alluvial fans; (3) the Olympic-Wallowa lineament; and (4) the Wallowa Mountains, with northeast-facing cirques. To the south, the Hurricane Creek glacial trough shows small moraines at its mouth. To the southeast, you

Figure 11. Columbia River basalt along Oregon Highway 82, discussed at Stop 12. Gray, massive basalt and red, scoriaceous basalt are cut by a small gray dike.

see the huge moraines of Wallowa Lake.

The Enterprise Gravel was defined and characterized by Spencer and Carson (1995). The unit includes silt, sand, gravel, and diamict and represents a braided-stream complex associated with a glaciofluvial environment and probable mudflows. Clast lithology and paleocurrent indicators show that the Enterprise Gravel was deposited by the ancestral Wallowa River that flowed north across the Joseph Upland—not northwest in the Wallowa Valley and parallel to the Olympic-Wallowa lineament as today. On the basis of magnetic polarity analyses and the presence of paleosols, a large assemblage of vertebrate fossils, and the Chief Joseph tephra of Spencer and Carson (1995), it was determined that the Enterprise Gravel is late Pliocene to middle Pleistocene. Vertebrates found at this exposure and in a gravel pit north of Enterprise include horse, pig, wolf or coyote, mammoth or mastodon, and bird (Figure 12). The unit is tilted to the south, which suggests neotectonism along the Olympic-Wallowa lineament.

Continue east on Oregon Highway 82 through Enterprise.

10.2 *At stop sign in downtown Enterprise, turn right (south) toward Joseph and Wallowa Lake.*

10.6 *Veer left (east), staying on Oregon Highway 82.*
The road straight ahead (south) is one route to Hurricane Creek.

14.0 Wallowa Lake moraines are straight ahead. The road goes south up the outwash fan.

16.2 *Enter Joseph* (elevation 4,190 ft).

16.7 *Turn right (west) on Wallowa Avenue.*
Note the cirques and avalanche tracks along the steep northeastern front of the Wallowa Mountains.

17.1 *Cross Wallowa River.*

17.9 The Joseph airport is on the right. The road climbs the Hurricane Creek outwash fan.

18.5 Moraines of the Hurricane glacier are visible ahead.

18.8 *Cross Hurricane Creek.*

18.9 *Turn left (south) on gravel road at Hurricane Grange.*

19.0 Cross terminal moraine of the Hurricane glacier, which was 21 km (13 mi) long and terminated at an elevation of about 4,200 ft (Allen, 1975). The next 1.1 mi show many small end moraines.

20.6 Till exposure.

20.8 *Enter Wallowa-Whitman National Forest.*
Here the west side of the Hurricane glacial trough has a huge talus accumulation. The cliffs above are Clover Creek Greenstone.

21.3 In the spring of 1999, the small creek here was subject to a hyperconcentrated flow event, which is transitional between water floods and debris flows. The sediment concentration in a hyperconcentrated flow is 40–70 percent by weight (Costa, 1987). The event occurred on the steep west slope of the Hurricane glacial trough, with most of the debris piling up at the base of the slope (see mile 22.6).

21.6 Stop 14 — Clover Creek Greenstone in Hurricane Creek valley
Road cuts for the next 0.4 mi are in the Clover Creek Greenstone of Permian and/or Triassic age (Baldwin, 1981). These volcanic and metavolcanic and associated rocks are the oldest part of the Wallowa terrane (Vallier, 1998). The unit includes lavas, pyroclastic rocks, and sediments, and, in the Hurricane Creek valley, greenstone breccia and conglomerate (Smith and Allen, 1941). These rocks are part of an ancient volcanic arc on which carbonate and clastic sedimentary rocks were deposited (Orr and others, 1992).

22.6 A large hyperconcentrated flow event (Costa, 1987) or debris torrent occurred here in the spring of 1999. A mud line high on the Douglas firs indicates the maximum height of the debris torrent. The debris extended across the valley and temporarily blocked Hurricane Creek. Above the road, natural levees can be seen beside the channel. Such events are common in the Wal-

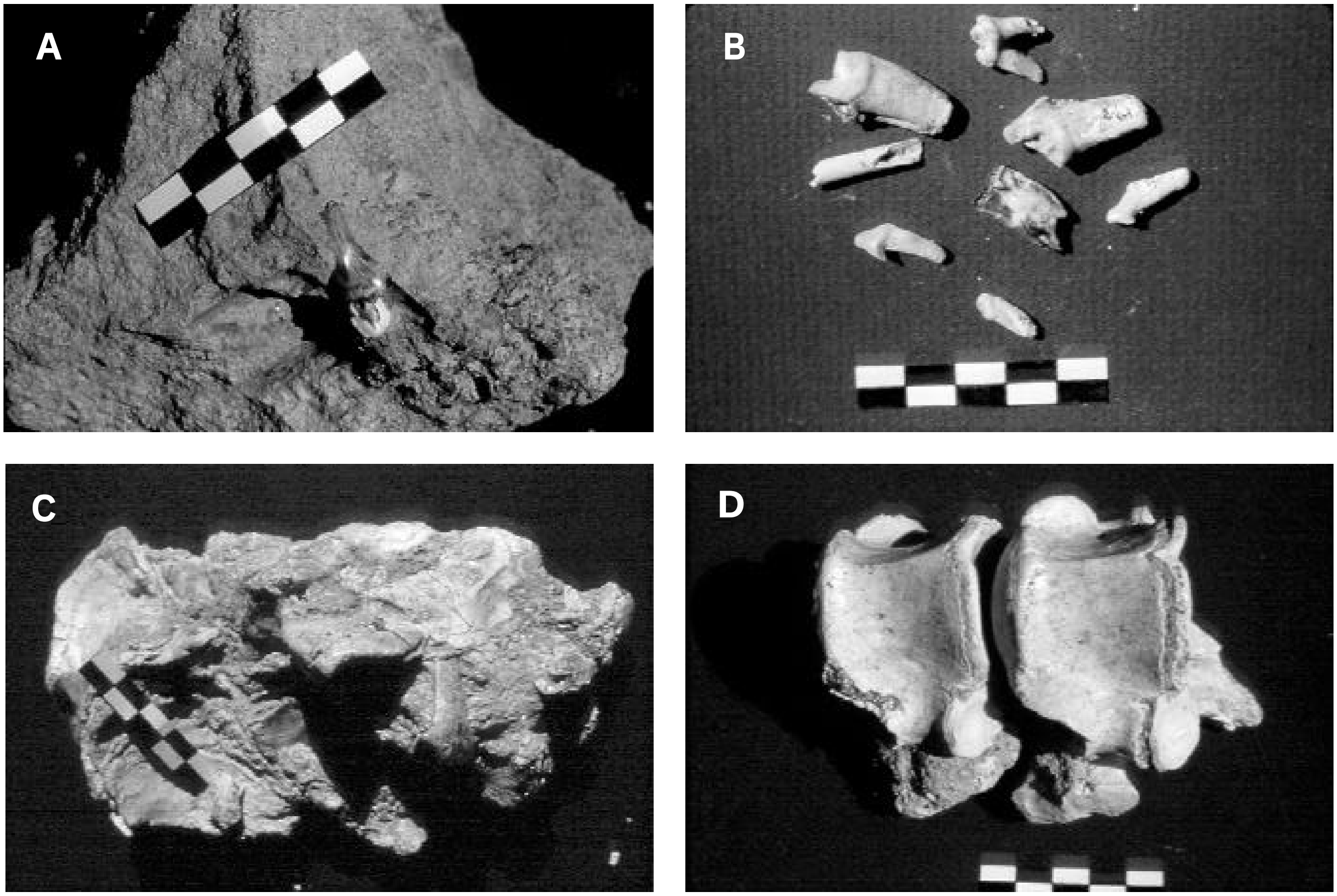

Figure 12. Vertebrate fossils from the Enterprise Gravel discussed at Stop 13. Scale bars in centimeters.

A. Canine tooth.

B. Carnivore tooth, horse teeth, and bird bone fragment.

C. Pig skull (occipital condyle).

D. Thoracic vertebrae of a horse.

E. Elephant scapula.

lowa Mountains. Slope and precipitation appear to be more important factors than bedrock lithology.

22.7 Stop 15 — Martin Bridge Limestone

Park in the lot at the end of the road.

Trail park permit required! Obtain at U.S. Forest Service office in Enterprise.

Walk south along the west side of the valley bottom of Hurricane Creek. In 200 m (650 ft), at a trail junction, go right (southwest) up Falls Creek trail. In another 200 m, you come to a switchback from which you have a good view. You can hear and see the falls of Falls Creek about 250 m (800 ft) to the southwest. The falls are supported by a cliff of Martin Bridge Limestone.

The Triassic Martin Bridge Limestone contains not only limestone and (where metamorphosed) marble but also sandstone and siltstone. The shallow-water platform limestone is as much as 500 m (1,600 ft) thick. In the southeastern Wallowa Mountains, the unit includes a coral reef (Vallier, 1998). Here, the Martin Bridge contains many sandstone layers and exhibits spectacular folds. Climb uphill a short way from the switchback to examine the strata. A summary of the sedimentology and stratigraphy of the Martin Bridge Limestone is contained in Follo (1994).

Falls Creek has been subject to floods and debris torrents. The surface of the alluvial fan downstream from here has been very active.

Walk back to the parking area and return to Joseph.

Part 6 — Joseph to the south end of Wallowa Lake

0.0 *Intersection of Oregon Highway 82 and Wallowa Avenue in Joseph.* This is close to the former terminus of the Wallowa glacier (Allen, 1975).

Drive south toward Wallowa Lake.

0.5 *Veer left at the sign to Wallowa Lake State Park.*
Moraines are visible approximately 1 km (0.6 mi) to the east and west.

0.8 Start crossing huge moraine complex.

1.5 Old Chief Joseph Gravesite and Cemetery on innermost end moraine.

1.6 *Parking lot for Wallowa County Park at south end of Wallowa Lake.*
The elevation (4,382 ft) of this moraine-dammed lake is controlled by the spillway at a small dam just to the west. The glaciolacustrine beds formerly exposed at the south end of the lake and recently covered with riprap indicate that in the past the lake was once a few meters higher. The lake is approximately 200 m (650 ft) deep, and the lateral moraines rise 250 m (800 ft) above the lake surface. The south end of the lake lies in the north end of a glacial trough.

2.0 Stop 16 — Till in right lateral moraine damming Wallowa Lake
From here you have an excellent view of both lateral moraines, the Olympic-Wallowa lineament along the steep northeast front of the Wallowa Mountains, and the glacial troughs along the East Fork and West Fork Wallowa Rivers. To the southwest, note the cirques on the northeast side of Chief Joseph Mountain (elevation 9,616 ft). Two of the major outlet glaciers from the so-called Wallowa ice cap (Allen, 1975) were along the Wallowa River; the West Fork Wallowa valley glacier was 21 km (13 mi) long, whereas the East Fork glacier was 9 km (5.6 mi) long.

Most of the large boulders in this till are granitics from the Wallowa batholith, but some are Clover Creek Greenstone. Some of the boulders are faceted and striated indicating subglacial transport.

Over the years, considerable controversy has raged over land use on the lateral moraines, concerning visual and water-pollution issues as well as potential geologic hazards. Developers want to build on the moraines because of the spectacular views from them and the proximity to Wallowa Lake. Yet the views are so magnificent partly because so few buildings exist on the moraines.

The gondola lift up Mount Howard, the peak on the south-southeast, is on the northwest side of the mountain. Other ski lifts and ski runs are proposed for the north and east sides of the mountain. Many of the lifts and runs, which would necessitate timber clearing, would be visible from the lake. The ski area would be linked to a destination resort.

5.6 View of the Wallowa River delta (ahead on right) and of the glacial trough along the West Fork of the Wallowa River.

6.0 *Junction, veer left (south).*
Road to the right (west) leads to Wallowa Lake State Park, just across the bridge over the Wallowa River.

6.2 Stop 17 — Gondola lift up Mount Howard
The Wallowa Lake Tramway is generally open from late May through September, from 10 a.m. to 4 p.m. or later (information phone number is 541-432-5331). Take warm clothes, buy tickets, and get on the tram (food and drink are available at the top of the tramway).

The tramway climbs up the east side of the glacial trough from 4,450 ft to 8,150 ft. In contrast to the cottonwoods, Douglas and grand firs, western larch, Engelmann spruce, and ponderosa and lodgepole pines in the valley bottom, the summit of Mount Howard has only Engelmann spruce, subalpine fir, and whitebark pine.

On the top of Mount Howard you will find more than 3 km (~2 mi) of walking trails (Figure 13). Early in the season, portions of the trails will be under snowbanks.

At the top, be sure to note the time of the last tram down the mountain!

At the head of the tramway (A in Figure 13), walk southwest to a junction (B); turn right (west), crossing a minor saddle and ascending a small hill (C) of vesicular lava of the Miocene Grande Ronde Basalt (Columbia River Basalt Group).

At point C, clockwise from south to northwest, the view is

South: East Peak, Miocene Columbia River basalt

Southwest: Bonneville Mountain on the arete between the glacial troughs along the East Fork and West Fork Wallowa Rivers—Jurassic-Cretaceous quartz diorite and granodiorite of the Wallowa batholith. Behind and just to the right of Bonneville Mountain, Eagle Cap—also part of the Wallowa batholith.

West-southwest: Matterhorn (bright white), marble of the Triassic Martin Bridge Limestone.

West: Hurwal Divide, an arete of the Triassic-Jurassic Hurwal Formation

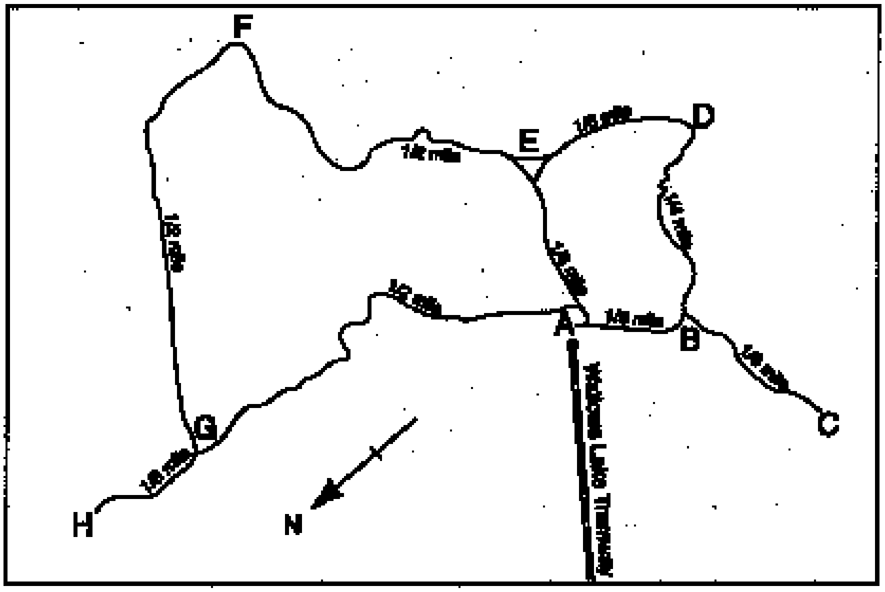

Figure 13. Map of walking trails on top of Mount Howard, Stop 17. A = top of tramway; D = summit of Mount Howard. Other letters used in text directions.

(clastic sedimentary rocks). Sacajawea Peak, at 9,839 ft the highest in the Wallowa Mountains, is hidden behind the Hurwal Divide.

West-northwest: Chief Joseph Mountain, mostly Triassic Lower Sedimentary Series

Northwest: Olympic-Wallowa lineament across Wallowa Lake

Return to the junction (B) and climb to the ***summit (D) of Mount Howard*** *(elevation 8,241 ft).* The rocks here consist of porphyritic lava of the Permian and/or Triassic Clover Creek Greenstone. To the southeast, you see east-dipping lava flows of the Miocene Columbia River Basalt Group. The dips of up to 25° show the arching of the Wallowa Mountain uplift (Taubeneck, 1987). Due east, across the canyon of the Imnaha River and Hells Canyon of the Snake River, lie the Seven Devils Mountains in Idaho. Most of these mountains are composed of the Triassic Wild Sheep Creek Formation, which is the younger part of the Clover Creek Greenstone (Vallier, 1998).

Continue counterclockwise around the top of Mount Howard. After a gentle descent to the northeast, you come to a junction (E). To the left (northwest) the top of the tramway (A) is only a short distance away. If you have time, go right, continuing northeast downhill to an overlook (F), and then northwest to another overlook at a junction (G). At this junction, turn right (north) and cross an alpine meadow to a ***small hill (H)*** *topped with what is known as a block field.*

Freeze-thaw activity has broken the Clover Creek Greenstone, which here has radiating clusters of plagioclase phenocrysts that have led to the local name "flowerstone" (Figure 14).

The view north-northwest shows the right lateral moraine complex of the Wallowa glacier (Figure 15) with more than a dozen individual moraine crests. Crandell (1967) divided the drift in the vicinity of Wallowa Lake into four ages, whereas Burke (1980) determined that only three ages of tills are present. To the northwest extends the left lateral moraine complex with about half a dozen moraine crests.

Visible also to the northwest is the Olympic-Wallowa lineament (OWL) (Figure 15). Grande Ronde Basalt is offset along the OWL more than 2 km (1.2 mi) from the Wallowa Valley on the downthrown northeastern side to outcrops high on some Wallowa peaks like Ruby Peak, Mount Howard, Aneroid Mountain, and Petes Point. About 120 km (75 mi) to the northwest along the OWL, near Milton-Freewater, where we started this field trip, a magnitude 6.1 earthquake occurred in this fault zone in 1936 (Brown, 1937).

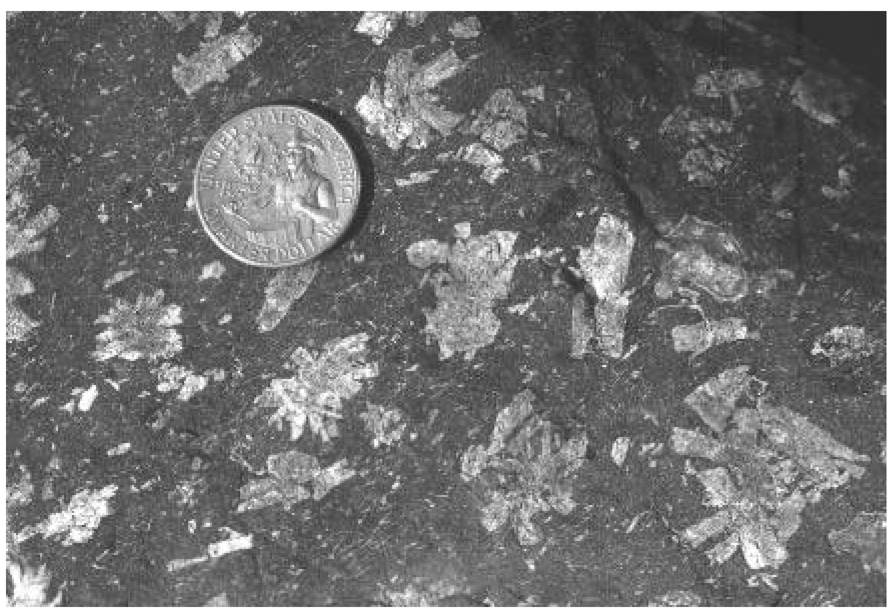

Figure 14. "Flowerstone" or Clover Creek greenstone with cumulophyric texture, as seen at Stop 17, point H. The Permo-Triassic porphyritic basalt with clusters of radiating plagioclase phenocrysts has undergone low-grade metamorphism.

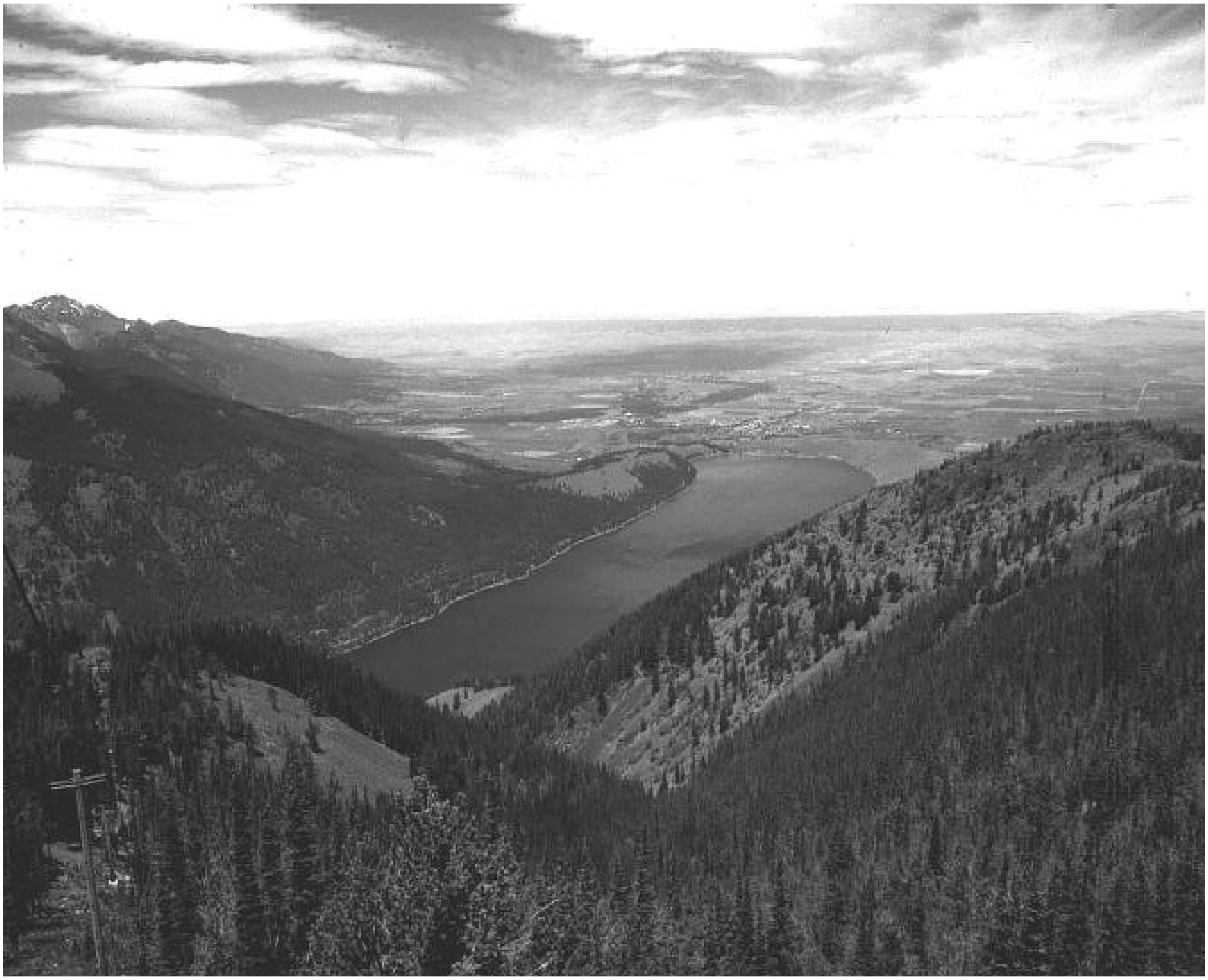

Figure 15. View northwest from near the top of Mount Howard, at Stop 17, point H. The Wallowa Mountains are in the foreground and on the left. At their base is the Olympic-Wallowa lineament (OWL). Off into the right distance is the Joseph Upland. Wallowa Lake and its prominent lateral moraines straddle the OWL.

To the north lies the Joseph Upland, capped with Grande Ronde Basalt. Beyond and more to the north-northwest, across the canyon of the Grande Ronde River, is the highest part of the Blue Mountains, located in southeastern Washington. The Blue Mountains are a giant northeast-trending anticline composed mostly of lava flows of the Columbia River Basalt Group.

Return to the junction (G) and the top of the tramway.

End of field trip guide.

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EDITOR'S GOSSIP

Honorable mention

Archie Strong deserves special praise as a stand-out volunteer for DOGAMI. He mainly helps in the Nature of the Northwest Information Center, where he is the person responsible for keeping the topographic maps in stock.

On February 20, 2001, we celebrate Archie's **91st birthday** with him! And the fact that he has volunteered **2,421 hours** of service to the department since 1992! Don't look any farther for a **shining example!**

Happy Birthday, Archie! And many more!

Dishonorable mention

With apologies we have to report that three of the latest DOGAMI publications **escaped from inclusion in the index** for volume 62 (year 2000) on page 123 of the last issue of Oregon Geology. But they did not get far: They are all listed on the same page (123) as that index, just above, not in it. Sorry!

In the neighborhood

The **Geological Society of Nevada** asks us to announce its **field conference** on May 3 to May 6, 2001, in Battle Mountain. Subject of the conference is "to study and exchange ideas on the role of tectonics and structure in the occurrence of, and search for, ore in northern Nevada and similar terranes worldwide." Participants are expected to "represent a broad spectrum of leading-edge scientists from industry, academia, and government." The conference will include **two days of talks and two days of field trips**, as well as "opportunities for poster, core, and prospect displays." Papers are to be published in a proceedings volume or a field trip guidebook. Contact for more information is Laura Ruud, Geological Society of Nevada, P.O. Box 12021, Reno, NV 89510-2021, 775/323-3500, e-mail gns@mines.unr.edu.

At home

April is Earthquake and Tsunami Preparedness Month! Statewide as well as at the local level, agencies and organizations concerned with keeping this preparedness awake and improving will soon publicize specific plans for the month. So **look for announcements** from such bodies as the Oregon Emergency Management, county emergency management agencies, local schools, or the Red Cross. Or ask them!

Remember: We may not be able to keep a natural disaster from happening, but we certainly can do a lot of things so that **a natural disaster** will not turn out to be **a civilization disaster**.

See also page 20 for a new publication available in the Nature of the Northwest Information Center. ☐

(Continued from page 12)

son Creek had higher ratios of peak/volume (20 percent increase), peak to antecedent precipitation (increases of 21–34 percent), and (peak/volume) to antecedent precipitation (increases of 32–48 percent).

The Tualatin had no streamflow changes even with a 1,000-percent increase in population. The Newaukum basin had unexpectedly large changes in basin response, given that its population density was lower than that of the Tualatin basin. The Johnson Creek basin was the most urbanized and showed significant streamflow increases in almost every category measured. These results suggest that the effects of urbanization on streamflow are a function of basin scale. Streamflow response to urbanization may become increasingly attenuated as basin size increases. ☐

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Places to see—Recommended by the Oregon Department of Geology and Mineral Industries:

Newberry Crater, heart of the Newberry National Volcanic Monument in Deschutes County, south of Bend.

The "crater" is, strictly speaking, a caldera—the remnant of a large shield volcano that collapsed during its eruptive life between about 500,000 and less than 2,000 years ago. With many eruptions continuing after the collapse, a great diversity of volcanic landforms and rock types was created here. This view to the south shows the central pumice cone that separates East and Paulina Lakes, with the Big Obsidian Flow stretching behind to the caldera rim.

Access from U.S. Highway 97 between La Pine and Bend is open from spring to fall. In winter, the road toward the caldera is cleared for 10 mi to a snow park area. You can call the Lava Lands Visitor Center at (541) 593-2421. See also page 20 above.