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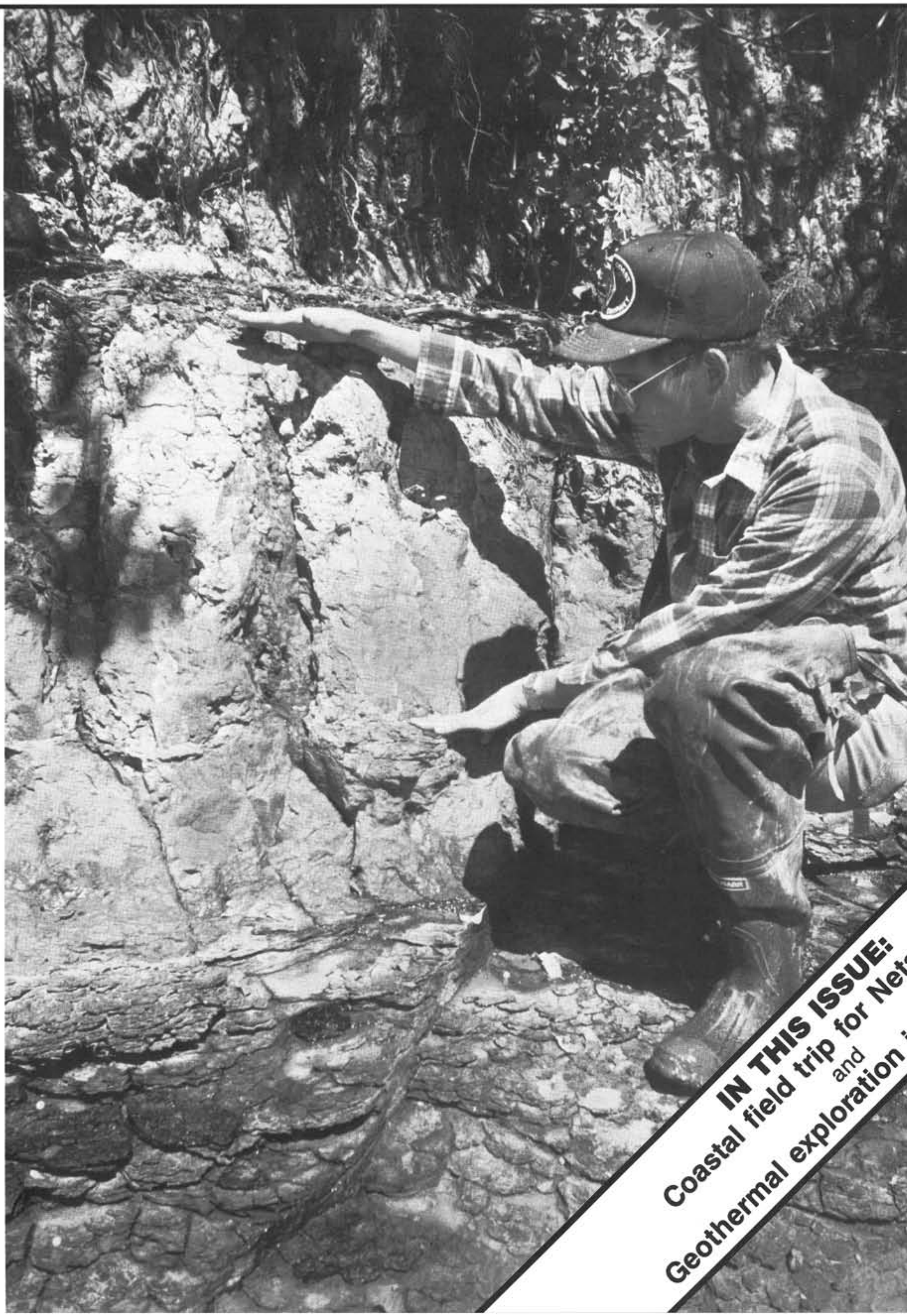

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and
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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Coauthor Mark Darienzo kneeling on a buried forest horizon and using his hands to indicate two other buried horizons above the first at Netarts Bay. Article and field trip guide beginning on next page present evidence of episodic abrupt coastal subsidence associated with convergent margin seismicity along the Oregon coast.

MLR announces changes in rules and procedures

As a result of recent legislative action (Oregon House Bills 2039 and 2041) and resultant changes in Division 30 rules, the following changes for holders of mining permits administered by the Mined Land Reclamation Program (MLR) of the Oregon Department of Geology and Mineral Industries have come into effect:

1. Bond reduction. If a permit holder (a) has conducted a mining operation at a permitted site for a minimum of 10 years without any substantial violations and (b) can demonstrate the financial ability to perform the reclamation required in the approved reclamation plan, then the permit holder is eligible to apply for a reduction in bond by an amount not to exceed 50 percent of the actual cost of reclamation estimated for the eventuality that the Department were to perform the reclamation.

The Department and industry interpret the condition of "no substantial violation" to mean that the operator has not willfully violated the approved reclamation plan or any operating provision of the pertinent statutes (ORS 517.750 - 517.900) and has a record of quick corrective response when notified of a noncompliance. It is not the intent of the Department to deny bond reductions to eligible applicants on the basis of procedural violations. However, continued procedural violations, at some point, might constitute a "substantial violation" and create a situation in which an operator would not be eligible or have such eligibility revoked.

Essentially, the bond reduction process is intended to encourage responsible operation, and the best indication of that is the test of time. The Department considers Oregon fortunate to have many responsible operators and operations.

The second criterion for eligibility, demonstrated financial capability to perform the required reclamation, is interpreted by the Department and industry in the following manner: Initially, the Department regards as sufficient testimony for credit-worthiness that an operation is currently bonded by a surety company or a letter of credit from a bank for the approved cost of reclamation. If the permit holder has a cash bond with the Department, a credit check may be required.

Permit holders who believe they are eligible for bond reduction are to notify the MLR office (see first inside page of this issue for address and phone number) at the time they submit their renewal payment. The Department will then review the bond calculations, make its decision on whether the permit holder qualifies, and establish the reduced bond amount.

Prior to any bond reduction, the Department will ensure that the bond is adequate to cover the cost of reclamation as proposed in the approved reclamation plan. In the past, there were per-acre ceilings on the cost of reclamation. According to the new House Bill 2041, the bond is set at the cost of completing the approved reclamation plan, including expected costs to the Department in contracting the work. The permit holder will be consulted by the Department in the process of determining bonding calculations and may appeal the resulting estimate of the bond to the State Geologist and the Department Board of Governors.

2. Renewal fee reduction. For those operators who have completed the approved reclamation plan, including all topsoil replacement and seeding, at the proper time and are waiting for vegetation establishment, the Department may reduce the renewal fee to $100.

3. Inspection fees. In addition to the annual fee, an additional fee of up to $100 may be assessed by the Department for inspection of sites where (a) mining is conducted without a valid operating permit, or (b) a surface mining operation has been abandoned, or (c) mining is conducted outside the permitted area.

*(Continued on page 115, **MLR**)*

Coastal neotectonic field trip guide for Netarts Bay, Oregon

by C.D. Peterson and M.E. Darienzo, College of Oceanography, and M. Parker, Department of Geology, Oregon State University, Corvallis, Oregon 97331

INTRODUCTION

This field trip guide summarizes the geologic evidence of episodic abrupt coastal subsidence that is recorded in late Holocene salt marshes and in uplifted late Pleistocene terrace deposits of Netarts Bay, northern Oregon (Figure 1). Similar records of abruptly buried marsh horizons have been identified in several other northern Oregon bays, including Alsea Bay, Nestucca Bay, Siletz Bay (Darienzo and Peterson, 1987), Salmon Bay, and Nehalem Bay (Grant and McLaren, 1987). However, the marsh sequences at Netarts Bay presently provide the longest and most unambiguous records of tectonic strain accumulation and strain release in coastal northern Oregon during late Holocene time (0-3,300 years B.P.). This is also the first coastal site in northern Oregon that has been observed to record multiple events of abrupt coastal subsidence in terrace deposits of late Pleistocene age.

In this field trip guide, we outline the general tectonic setting of coastal Oregon and briefly discuss some of the controversies concerning convergent margin seismicity in the southern Cascadia margin. This field trip guide contains detailed core logs of the marsh sequences of late Holocene age in Netarts Bay, which include some seven events of tidal-marsh burial. Since tidal marshes grow within a restricted range of mean sea level, their episodic burials provide a record of the accumulation and release of vertical tectonic strain. The approximate ages of the seven marsh burial events in Netarts Bay are provided by ^{14}C dating analyses of the buried peat horizons. Finally, we describe several field locations at Netarts Bay, both on the modern marsh and along exposed Pleistocene terraces, where wetland burial events can be observed directly in the geologic sections.

This field trip guide is an outcome of a coastal neotectonics field trip to Netarts Bay in May 1988 that was sponsored by the College of Oceanography and the Department of Geology at Oregon State University. The field trip was attended by staff and students from Oregon State University, the University of Oregon, and the Oregon Parks and Recreation Division, which manages the Cape Lookout State Park at Netarts Bay. We thank the field trip participants for their questions, observations, and field trip photographs that we have incorporated into this guide.

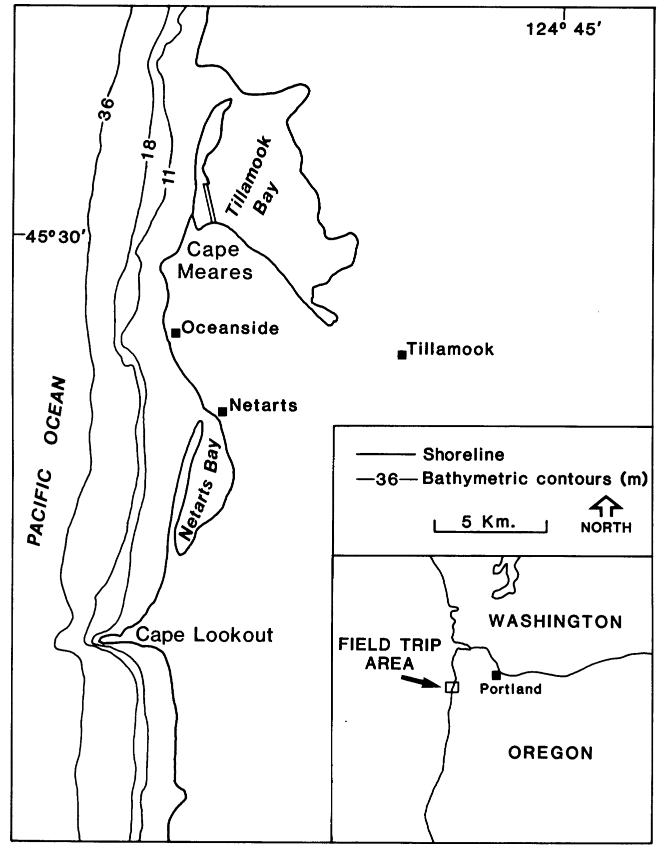

Figure 1. Map of study site. The field area is located some 55 km due west of the Portland metropolitan area (inset). Netarts Bay is situated between two headlands, Cape Lookout and Cape Meares, and is protected from the ocean by a barrier spit that extends nearly to the northern end of the coastal lagoon.

TECTONIC SETTING OF COASTAL OREGON

The Cascadia continental margin extends approximately 1,000 km from the Queen Charlotte Islands in southern British Columbia to Cape Mendocino in northern California (Figure 2). This continental margin comprises the region that is bounded to the west by the young oceanic Juan de Fuca Plate and to the east by the continental North American Plate. The nature of plate convergence along this margin is controversial. Recent studies of deep, small-scale seismicity in the northern Cascadia margin of Washington define the geometry of a descending subcrustal slab, confirming the subduction of the Juan de Fuca Plate under the North American Plate (Crosson and Owens, 1987; Weaver and Baker, 1988). In contrast, locked-plate deformation is indicated along the coast of northernmost California by folding and thrusting of Pleistocene and Holocene sequences (Carver and Burke, 1987). These belts of deformation are attributed to west-east plate convergence and to northward migration of the adjacent Mendocino triple junction, which is the conjunction of the Mendocino fracture zone and the San Andreas fault (Figure 2). The transition between the fold and thrust belts in northern California and the active plate subduction in Washington must occur somewhere along the Oregon coast, but where?

Although western Oregon comprises about a third of the Cascadia subduction zone, it has not experienced a substantial subduction zone earthquake in historical time. In fact, historic seismicity in the Juan de Fuca Plate has consistently shown north-south compression (Rogers, 1983; Weaver and Smith, 1983). The lack of large-scale subduction seismicity has been attributed to either terminated subduction or aseismic slip of the underthrusting plate. However, the historical record (<200 years of aseismicity) might be too short to rule out coseismic subduction processes (Heaton and Kanamori, 1984). Past events of large-scale subduction zone seismicity (Chile, 1960; Alaska, 1964) have produced rapid coastal subsidence associated with vertical tectonic strain release (Heaton and Hartzell, 1986). Multiple events of abrupt coastal subsidence have been reported from wetland burial sequences of late Holocene age in southwest Washington (Atwater, 1987). These wetland records con-

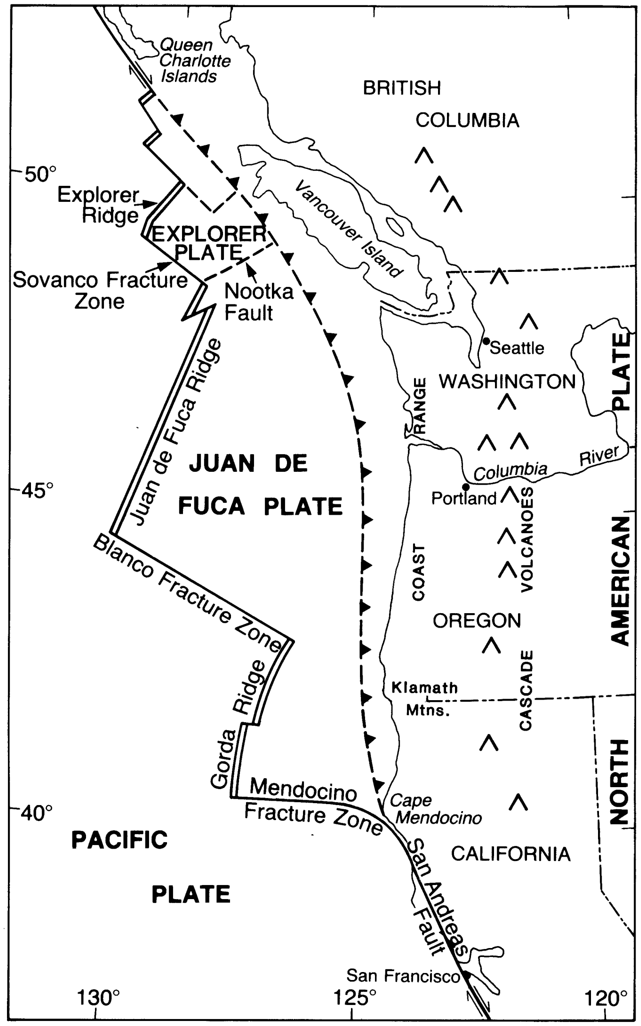

Figure 2. Tectonic map of the Cascadia Margin. Convergence of the Juan de Fuca oceanic plate with the North American continental plate occurs between the Queen Charlotte Islands in southern British Columbia and the Mendocino triple junction in northern California. A transition from plate subduction in the northern part of the margin to locked-plate deformation in the southern part of the margin probably occurs in Oregon.

firm active subduction tectonics and argue for coseismic strain release in the northern Cascadia margin. The question that immediately arises is, has the southern Cascadia margin experienced similar subduction strain release events in late Holocene time?

GEOLOGIC SETTING OF NETARTS BAY

Netarts Bay is located some 55 km due west of the Portland metropolitan area, on the west slope of the northern Oregon Coast Range (Figure 1). The field site is isolated from the Tillamook Bay drainages to the east by a resistant sandstone ridge that bridges two topographic highs comprised of Columbia River Basalt Group flows. These basalt flows form two coastal headlands, Cape Lookout and Cape Meares, to the south and north of Netarts Bay, respectively. Differential coastal erosion during Pleistocene high stands of sea level produced the Netarts embayment between the two capes. Sand trapped between the headlands during the Holocene transgression apparently formed the present sand spit barrier of Netarts Bay (Figure 3). Estuarine deposits within Pleistocene terrace sections on the east side of Netarts Bay indicate a protected depositional setting in late Pleistocene time as well. These young Pleistocene deposits are probably correlated with the Whisky Run terrace, dated at about 83,000 years B.P. (West and McCrumb, 1988). Although northwest-trending fault sets cut Tertiary rocks to the east of Netarts Bay, no faults have been observed in exposed Quaternary terraces along the bay shoreline.

Netarts Bay was chosen for our work on late Holocene changes in relative sea level on the basis of its unique physiography and hydrography (Darienzo, 1987). The salt marsh at the southern end of Netarts Bay is protected from ocean storms by the barrier sand spit that extends to the northern end of the bay (Figure 1). In addition, the marsh is unaffected by river flooding, since only minor tributaries enter this coastal lagoon. Records of episodic high-marsh burial by intertidal mud flats or of rapid marsh progradation over bay tidal flats should document changes of relative mean sea level and not effects of extreme climatic conditions. Since global sea level has not varied greatly within the last few thousand years (Clark and Lingle, 1979), any dramatic changes in local sea level should reflect vertical tectonic movements of the coastal region.

LATE HOLOCENE MARSH RECORDS IN NETARTS BAY

The late Holocene stratigraphy of the Netarts marsh has been documented in cores 4-5 m in length that have been taken along two transects that cross the length and width of the marsh system (Figure 4). The marsh core sites were surveyed into a temporary tide gauge station to reference all core horizons to local mean tide level (MTL). Two types of cores, including continuous cores (5-7.5 cm in diameter) and 1-m-interval cores (2.5 cm in diameter), were recovered at the marsh core sites. The 1-m-interval cores were used primarily to establish accurate depths of stratigraphic horizons, since the continuous cores averaged about 10 percent compaction during coring of the soft sediments. The continuous cores were used for detailed sediment and microflora analyses, which are currently being compiled for publication. Radiocarbon dating of the buried peats from returned core samples was performed by Beta Analytic, Inc., using standard pretreatment leaches to remove potential contaminants. Peat dates are adjusted by $^{12}C/^{13}C$ ratios, and all sample dates are calibrated by ^{14}C reservoir fluctuations (Stuiver and Reimer, 1986).

The preliminary results of the marsh coring and sample analytical work are shown in marsh stratigraphic sections trending west-east (Figure 5a) and north-south (Figure 5b). The stratigraphic sections document a series of repeating marsh burial sequences that are easily traced thoughout the marsh system. A typical burial sequence starts with a peat horizon that is overlain by a capping layer of sandy or silty sediments that is, in turn, overlain by finely laminated bay muds that grade upward into another peat horizon (Figure 6). Stratigraphic correlations across the marsh core sites show that the buried marsh horizons generally thin or are sometimes completely missing toward the central part of the Netarts marsh. The most complete records of marsh burial events are contained in cores from the bay margins, sites 5, 7, and 10, where rapid sedimentation and minimal erosional disturbance encourage quick marsh recovery from episodic burial.

A total of some seven marsh burial events are recorded in the upper 5 m of the Netarts marsh. Only the first and third buried horizons are generally visible in exposed sections of tidal creek cuts, between core sites 11, 8, and 12, or along the northern marsh scarp near core site 9 (Figure 4). The low organic muds covering the buried peat horizons vary from 0 cm to 100 cm in thickness. The vertical distances between the tops of successive peat horizons are also variable, ranging from 25 cm (between burial events 2 and 3 in core 7) to 175 cm (between burial events 4 and 5 in core 11). In some cases, a buried peat horizon is directly overlain by finely laminated muds, as shown by the second buried marsh horizon near zero-m depth (MTL) in cores 5, 7, and 10, and by the fifth and sixth buried peats at about 2.5-m depth (MTL) in cores 5, 10, 11, and 13 (Figures 5a,b). This buried peat couplet is anomalous in several respects and requires additional study before its origin can be interpreted.

Figure 3. Netarts Bay. View to north of Netarts Bay, spit, and ocean from field trip stop 1.

EVIDENCE OF ABRUPT COASTAL SUBSIDENCE IN MARSH RECORDS

The multiple sequences of peat burial by bay muds in the Netarts marsh cores document a process of episodic rise and fall of relative sea level due to vertical tectonic forcing. The buried peat layers in Netarts Bay were formed in high marsh settings at supratidal elevations. Many of these buried peat layers contain fresh-water diatom assemblages. Since Netarts Bay is a salt-water lagoon, the fresh-water microflora must represent fresh-water ponding on supratidal marshes during rainy periods. In contrast, the finely laminated muds that overlie the buried peat horizons contain marine-brackish diatom assemblages, which indicate that these muds were deposited at intertidal to subtidal elevations. The high marsh horizons must have subsided at least 1 m relative to the corresponding sea level to be buried by the tidal-flat muds. The measured vertical distances between several buried marsh horizons (<1 m) indicate some coastal emergence by tectonic strain accumulation between strain release events.

Significantly, the transitions between high marsh peats and overlying barren sediments in the first four burial sequences are extremely abrupt, usually occurring over distances of several millimeters (Figures 5a,b). The sediment-capping layers above three of the upper four buried marshes also indicate very rapid subsidence and initial burial. The sediment-capping layers are typically rich in sand and lack any evidence of traction current deposition by ripple or dune migration. They appear to have been deposited out of suspension from highly turbulent flows. Individual sediment-capping horizons do vary in thickness from one core site to the next but can be traced across the full extent of the marsh system. The widespread distribution of the thin capping layers indicates a system-wide mechanism of sand and silt transport over the broad marsh surfaces. Such a large-scale sheetflood could be produced only by a very rapid change in sea level, possibly associated with a tsunami or internal basin seiche, following an abrupt subsidence event.

RADIOCARBON AGES OF BURIED MARSH HORIZONS

The radiocarbon ages of the buried marsh (BM) horizons from adjacent core sites 5 and 11 range from the most recent at about 400 years B.P. (BM sequence 1) to 3,300 years B.P. (BM sequence 7) as shown in Figure 7. The age of the marsh layer must predate the actual marsh burial, so the marsh dates represent maximum radiocarbon ages of past subsidence events. Both the tops and bottoms of marsh layers in BM sequences 1, 3, and 4 were dated to bracket radiocarbon ages of the burial events and to estimate duration of marsh recovery from successive burial events. The greatest duration in radiocarbon age between burial events is on the order of 1,000 years (between BM horizons 4 and 5), while the shortest interval is possibly less than 100 years (between BM horizons 3 and 4 and between BM horizons 5 and 6). In addition, the first buried marsh (BM 1) was dated at three locations in site 5, and the three dates—top = 370±60 radiocarbon years B.P. (RCYBP), middle lower = 690±110 RCYBP, and bottom = 1,240±80 RCYBP—demonstrate the potential age range of a single marsh unit.

Radiocarbon age reversals are apparent between the top and bottom of BM 3, between BM horizons 5 and 6, and between the bottom of the modern marsh and top of BM 1 (Figure 7). Such reversals might result from descending roots or organic fluids that transport radiogenically young carbon across marsh units. While

NETARTS BAY SALT MARSH CORE SITES

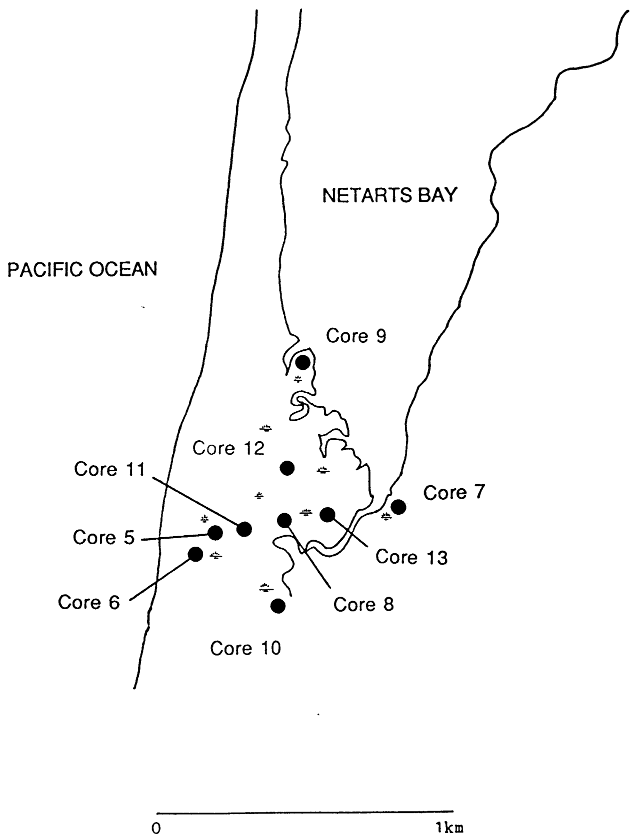

Figure 4. Map of selected core sites in southern marsh system of Netarts Bay. Core sites were chosen to form two transects that cross the full width of the marsh system from west to east and from north to south.

radiocarbon dating of the buried marsh horizons has obvious limitations in absolute age resolution, it does set important constraints on the timing and frequencies of past strain release events. Events of abrupt tectonic strain release have occurred throughout the late Holocene, and the observed recurrence intervals are clearly quite variable. Longer records of Holocene marsh burials are needed to better understand the tectonic cycles of strain accumulation and strain release in this part of the Cascadia margin.

EPISODIC MARSH BURIAL IN TERRACE DEPOSITS OF LATE PLEISTOCENE AGE

Protected tidal-basin deposits in uplifted terraces along the eastern side of Netarts Bay show evidence of multiple coastal subsidence events in late Pleistocene time. The Pleistocene terrace deposits pinch out against sedimentary and volcanic units of Tertiary age to the east of the Netarts embayment (Figure 8). However, 5- to 10-m-thick sections of the terrace deposits are locally well exposed along the southeast shoreline of Netarts Bay. The terrace deposits vary from estuarine deposits in the northern exposures near Whiskey Creek to fluvial channel-fill gravels and colluvial debris in the southern exposures near Austin Creek (Figure 8). A small mudflow deposit also occurs in the terrace section near Austin Creek and further denotes the processes of downslope mass transport in the vicinity of the high-relief volcanic units at the south end of Netarts Bay. The northern exposures of estuarine deposits are characterized by laminated tidal-flat muds with intervening layers of organic-rich material (Figure 9). The organic layers can be traced continuously along distances of at least 100 m, and they locally contain tree trunks rooted in place (Figure 10).

Some three to five organic-rich layers are observed within three 4-m vertical sections near Whiskey Creek (T1, T2) and Wee Willie's Restaurant (T3), as shown in Figure 9. The lower contacts between the organic layers and underlying laminated muds are gradational, while the upper contacts between the organic layers and the overlying muds are consistently abrupt (Figure 11). Sand-rich capping layers were not observed above the buried organic layers in the terrace outcrops. The alternations between bay muds and at least two wetland forest horizons are very striking and are similar in appearance to buried wetland soils in deposits of late Holocene age in southwestern Washington (Atwater, 1987). The magnitudes of coastal subsidence required to bury the wetland forest horizons with bay muds in the exposed late Pleistocene sections are certainly greater than those required to bury the tidal-marsh horizons in the sequences of late Holocene age of the Netarts marsh. The probable age of the Pleistocene terrace deposits (at least 83,000 years B.P.) precludes the use of ^{14}C dating to estimate the recurrence intervals between the burial events.

CONCLUSIONS

1. The protected tidal marshes of the Netarts coastal lagoon provide an ideal setting for the recording of vertical tectonic movements associated with convergent-margin strain accumulation and strain release.
2. The late Holocene record of marsh stratigraphy contains evidence of some seven separate events of coastal subsidence, as documented by supratidal marsh burial under intertidal bay muds. Sharp contacts above five of the buried marsh horizons indicate very abrupt burial.
3. At least four of the late Holocene burial events are associated with sediment-capping layers, which are interpreted to have been deposited out of suspension from catastrophic sheetfloods over the subsided marsh system.
4. The evidence of episodic coastal subsidence in Netarts Bay and from nearby estuaries documents multiple events of rapid tectonic strain release associated with active subduction processes in northernmost Oregon during late Holocene time.
5. The processes of tectonic strain accumulation and rapid strain release that are recorded in the late Holocene marshes of Netarts Bay can be traced back to late Pleistocene time in adjacent bay terrace deposits.
6. At least two events of wetland forest burial by bay muds in the exposed late Pleistocene sections required greater magnitudes of vertical subsidence than has been observed in late Holocene sequences of tidal marsh burial in Netarts Bay.

ACKNOWLEDGMENTS

Radiocarbon dating of selected peat horizons in the initial pilot study of late Holocene sea-level changes in Netarts Bay was supported by the Oregon State University Sea Grant College Program. Funding for the investigation of episodic tectonic strain release in Netarts Bay was provided by the U.S. Geological Survey, under the National Earthquake Hazards Reduction Program, Grant Number 14-08-0001-G1512. The Oregon Department of Geology and Mineral Industries assisted with figure drafting and photographic reproductions used in this field trip guide. We thank Tariq Jaswal for his contribution of several field trip photographs used in this guide.

FIELD TRIP STOPS 1-5

Access to Netarts Bay, Tillamook County, is by the Three Capes Scenic Route, a loop west of State Highway 101 between Pacific City in the south and Tillamook in the north. All field trip stop locations are along this Scenic Route and are shown in Figure 12.

Bring: small shovel, rubber boots or waders, and tide table.

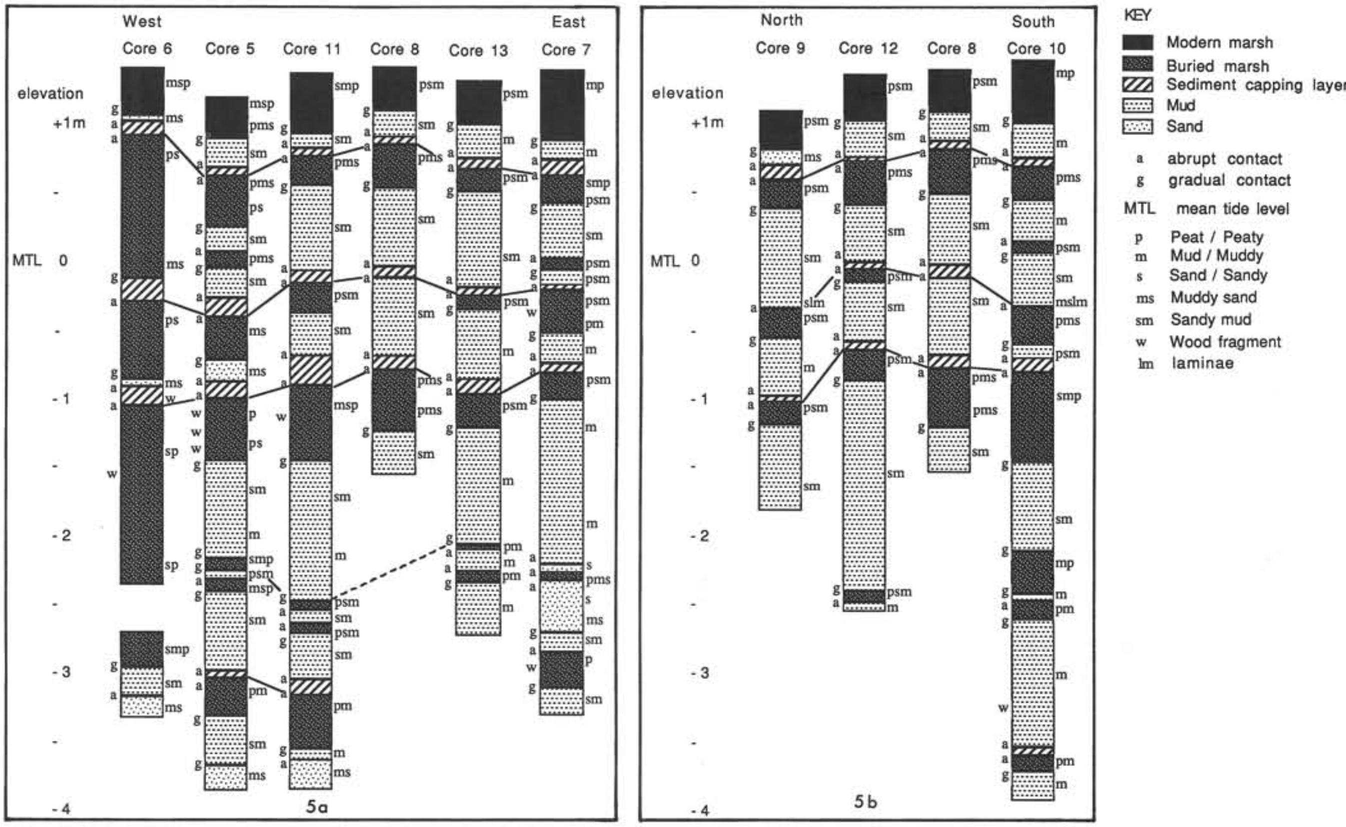

Figure 5. Core logs and stratigraphic correlations between core sites are shown in Figures 5a (west-east transect) and 5b (north-south transect). The types of contacts between depositional units are shown on the left of each core log, while the sediment composition is shown on the right (see key for definitions). At least seven distinct marsh horizons are apparent in the late Holocene stratigraphic sections.

Figure 6. Mark Darienzo (right) and Bob Yeats, Department of Geology, Oregon State University, looking at buried marsh layer in interval core from Netarts Marsh.

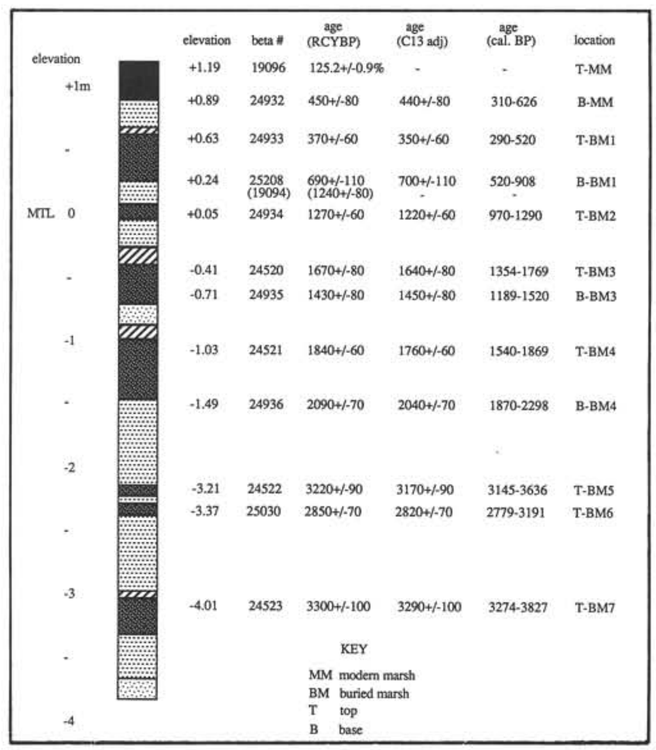

Figure 7. Core log and radiocarbon dates from core sites 5 and 11. Buried marsh horizons range in radiocarbon age from about 400 years to about 3,300 years B.P. Calibrated ages are based on sample two sigma deviations about ^{14}C calibration curves established from tree-ring data (Stuiver and Reimer, 1986).

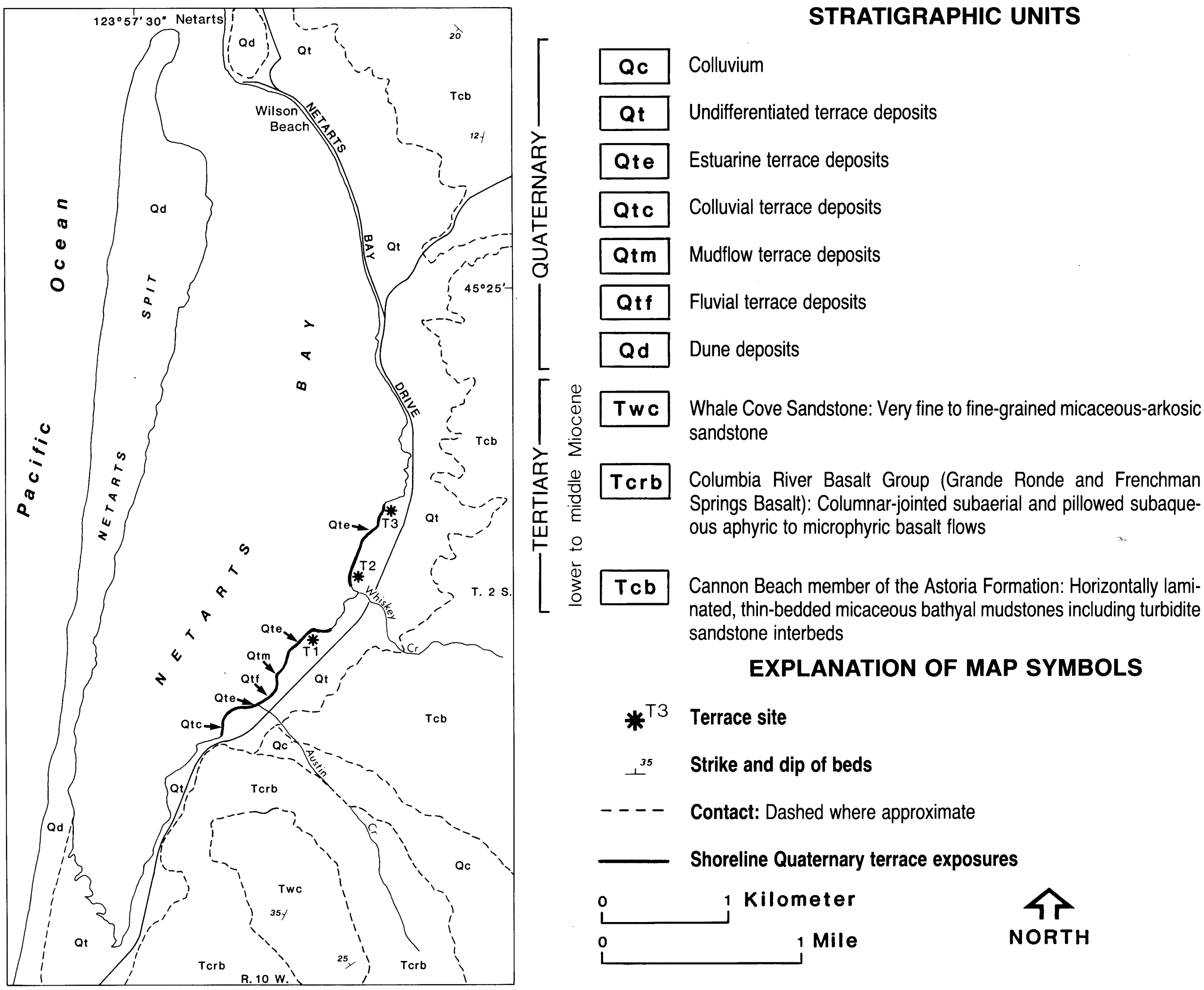

Figure 8. Preliminary geologic map of the Netarts Bay area and late Pleistocene terraces. The terrace deposits shift from interlayered wetland horizons and laminated bay muds to the north of Whiskey Creek (see Figure 9) to fluvial and colluvial deposits in the southernmost terrace exposures, which are adjacent to high-relief volcanic units. Mapped by M. Parker.

STOP 1: Anderson's Viewpoint, north of parking lot for Cape Lookout trailhead and south of Cape Lookout State Park.

From this site, one can look north to Netarts Bay. Netarts Bay is a shallow coastal lagoon located within a littoral cell bounded by Cape Meares to the north and Cape Lookout to the south. The bay is separated from the Pacific Ocean by a long narrow sand spit. The geology of the surrounding area is summarized in Figure 8. The salt marsh at field trip stops 2 and 3 is located at the southern end of the bay and is partially visible from this viewpoint. Pleistocene terrace outcrops (stops 4 and 5) are located on the southeastern side of the bay.

STOP 2: Tidal creek cuts in Netarts Bay salt marsh

Park vehicle in day use area at Cape Lookout State Park and walk to the salt marsh through the campground. Easiest access to the marsh is via campsite B-44. Wear rubber boots and watch out for small channel cuts hidden by the tall marsh vegetation. The lowest tide of the day is the best time to view the stratigraphy along the creek banks.

The marsh surface is relatively flat and occupies a narrow elevational zone (1-1.5 m above mean tide level) within the bay. The marsh is a high marsh containing plants such as *Deschampsia* (tufted hairgrass), *Juncus* (rush), and *Potentilla* (silverweed). Proceed to the tidal creek near core site 8 (Figure 4). At low tide, the first and possibly third buried marsh horizons will be visible. At core site 8, the second and third buried marshes are absent. Only the sediment-capping layer is associated with the third burial event at this location, and it is recognized by a thin layer (about 10 cm thick) of alternating mud and sand laminae. The second buried marsh was not present in any of the interior core sites (Figures 4, 5a,b). The sediment-capping layer immediately above the first buried marsh horizon is locally entrenched in the tidal creek bank due to differential erosion of this sand-rich layer.

If the present marsh surface dropped abruptly by 1 m, its surface elevation would then be very close to the elevation of the barren tidal flats just north of core site 9. A rapid displacement of coastal water masses in association with the abrupt coastal subsidence could scour available sand and silt and redeposit these sediments in an anomalous capping layer above the subsided marsh horizon. Mud

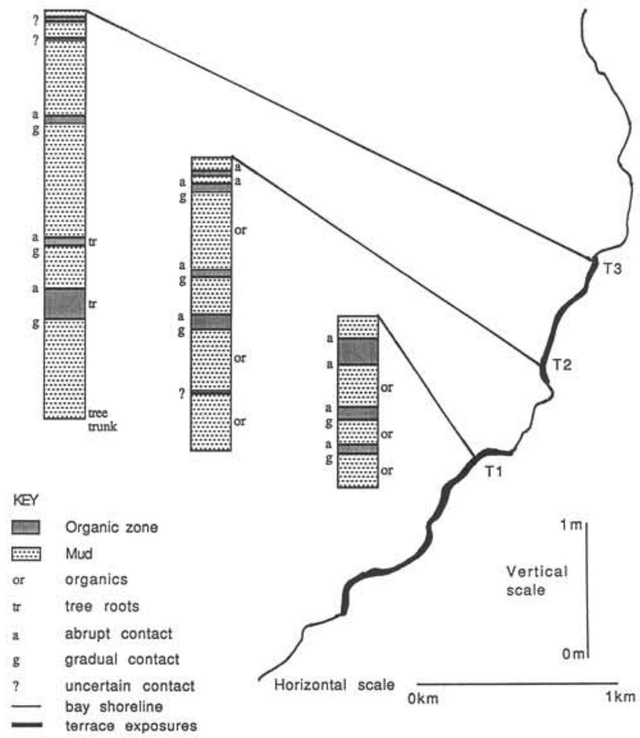

Figure 9. Preliminary stratigraphic sections of buried wetland horizons in terrace deposits exposed along the southeast margin of Netarts Bay (see Figure 8). A total of five burial sequences are observed at terrace sites T2 and T3. Rooted trees are associated with two to three buried horizons in the exposed Pleistocene sections.

and silt laminae would be deposited by the tides and by wind-wave action, and this would eventually raise the tidal flat to an elevation where marsh plants could recolonize the bay muds. Tectonic emergence between subsidence events could accelerate the low marsh progradation and its subsequent transition to a high marsh setting.

STOP 3: Marsh scarp at marsh/tidal-flat boundary

Proceed through gate at northwestern end of campground (no vehicle access) and follow dirt road north. The road narrows and becomes a trail. Continue walking until you reach the most northwestern part of modern marsh scarp (Figure 13). This point can be recognized by a "no hunting" sign along the bay edge 30-40 m east of the trail. From the sign, walk southeast to the marsh scarp.

At low tide, the first and possibly the third buried marsh horizons will be visible. At core site 9 (Figure 4), the second buried marsh was not present (Figure 5b), and it is likely absent along much of the northern scarp. The sediment-capping layer above the first buried marsh is usually visible as a differentially eroded layer of muddy sand and can be followed along most of the scarp. Occasionally, the sediment-capping layer is found intact in relatively protected pockets. X-radiographs of this capping layer indicate a lack of any small-scale cross-bedding or plane bed striations.

The 1-m-high scarp cutting the modern marsh and the first burial horizon is present along nearly the entire northern boundary of the salt marsh system. The scarp is an erosional feature formed by local wave and current action. The presence of an erosional scarp and absence of a progradational marsh front (except along the eastern side of the bay spit) suggest that rapid tectonic emergence is not presently occurring at Netarts Bay.

STOP 4: Pleistocene terrace outcrops near Whiskey Creek

Drive north to Wee Willie's Restaurant. Access to the bay shoreline and terrace exposures is via a trail through the salt marsh at the northern end of Wee Willie's parking lot. Walking south along the tidal flat to Whiskey Creek is possible during low tide. The late Pleistocene terrace outcrops are located both north and south of Whiskey Creek, with the best exposures of buried wetland forest horizons to the north of Whiskey Creek. This stop includes T1 and T2 on Figures 8 and 9.

Alternating layers of laminated mud and of dense organics are visible in the exposed terrace sections. Two of the organic layers at T2 locally contain protruding tree trunks and roots. The dense organic layers are buried Pleistocene wetlands that apparently range from incipient marshes (very thin organic layers) to forested soil horizons. The upper contact of each of the organic layers with the overlying laminated bay muds is sharp, indicating abrupt subsidence and rapid burial rather than gradual subsidence. However, no sediment-capping layer (e.g., sand layer) is present immediately above the dense organic layers.

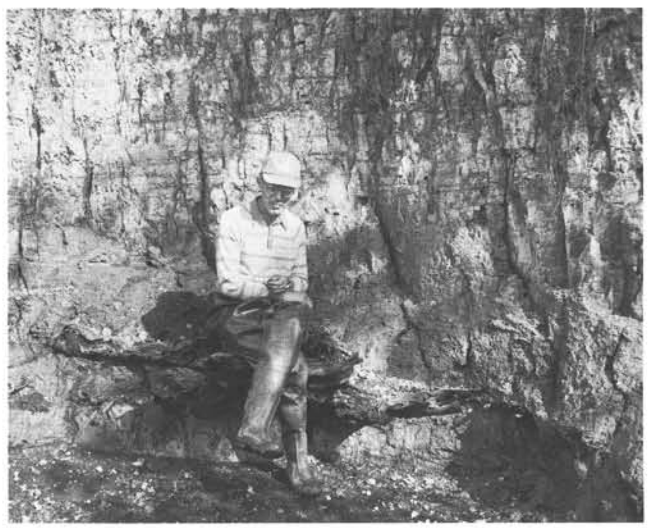

Figure 10. Terrace outcrop 2, with Bob Yeats sitting on buried tree trunk in wetland soil horizon.

Figure 11. Three organic layers buried by terrace deposits (unit T1) of late Pleistocene age in Netarts Bay. Uppermost layer is partially obscured by vegetation at field notebook (18 cm high, for scale).

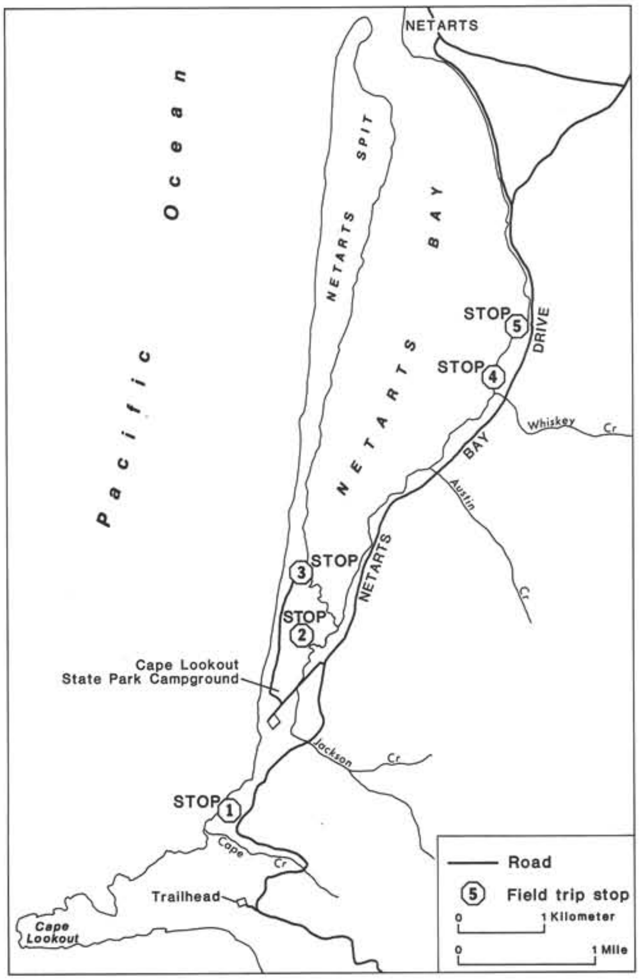

Figure 12. Location of field trip stops 1-5.

STOP 5: Pleistocene terrace outcrop near Wee Willie's Restaurant

Walk back to the tidal flat and terrace exposures north of Wee Willie's Restaurant. This stop includes T3 on Figures 8 and 9.

At low tide, numerous tree stumps are exposed on the modern tidal flat. A few of the tree stumps are close to the base of the vertical terrace exposure. Trenching through the thin cover of modern muds will expose the base and roots of the tree trunks that are rooted in the Pleistocene terrace deposits. The tree stumps on the tidal flat are in situ and are remnants of Pleistocene forest horizons exhumed during erosion and retreat of the bay cliff. Tree roots can be seen protruding out of an additional organic-rich layer about 1 m above the base of the bay cliff. Several additional organic-rich layers of varying thickness are also visible above the wetland forest horizons. In all cases, the organic-rich layers have abrupt upper contacts and gradual lower contacts with intervening laminated bay muds.

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*(Continued on page 117, **Netarts Bay**)*

Figure 13. View to the south of bay flats and marsh scarp at field trip stop 3.

Geothermal exploration in Oregon, 1987

by Gerald L. Black and George R. Priest, Oregon Department of Geology and Mineral Industries

LEVEL OF GEOTHERMAL EXPLORATION

Introduction

In 1987 there was no new geothermal gradient drilling in the young volcanic rocks of the High Cascades. There was, however, moderate activity at Newberry Crater. The amount of leased land declined on both U.S. Bureau of Land Management (USBLM) and USDA Forest Service (USFS) lands. The total amount of Federal land leased for geothermal resources has declined annually by small amounts since the peak in 1983.

Drilling activity

Figure 1 shows the number of geothermal wells drilled and geothermal drilling permits issued from 1970 to 1987. No new permits were issued, and only two new geothermal-gradient wells were drilled. Table 1 lists the Department of Geology and Mineral Industries (DOGAMI) permits for geothermal drilling that were active in 1987. The decrease in drilling resulted from poor market conditions for electric power and from other factors, such as the termination of the U.S. Department of Energy (USDOE) program that provided matching funds for temperature-gradient drilling and appeals filed as part of the regulatory process concerning the California Energy Company, Inc., (CECI) drilling project near Crater Lake.

The USDOE program had focused on exploration of the High Cascades, Newberry volcano, and Medicine Lake volcano in California. This focus resulted in the completion of temperature-gradient holes northwest of Mount Jefferson, on the flanks of Mount Mazama (Crater Lake area), and at Newberry Crater. No new solicitations are planned for this program. One contract with CECI for drilling at Mount Mazama remains active.

Two temperature-gradient wells were drilled by GEO-Newberry Crater, Inc., a subsidiary of Geothermal Resources International, Inc., on the east and southwest flanks of Newberry volcano. Both holes were permitted to 5,000 ft, but the actual total depth drilled and other data from the holes are proprietary.

Figure 2 shows the number of geothermal prospect-well permits issued and wells drilled from 1970 to 1987. No wells have been drilled or permits issued since 1984 for shallow (less than 2,000 ft) temperature-gradient work. This trend is a result of the shifting focus of exploration from eastern Oregon to the Cascade Range, where deeper temperature-gradient wells are required to penetrate the "rain curtain."

Leasing

The consolidation of land holdings continued in 1987 as the total leased acreage of Federal lands decreased by about 12 percent (Table 2; Figure 3). This decrease in leased lands was the result of a 56-percent decline in USBLM noncompetitive leases, coupled with a 10-percent rise in USFS noncompetitive leases (Table 2). This decrease marks the fourth straight year of decline since the total leased acreage peaked in 1983.

A total of 119 leases are pending on USFS lands in Oregon. The majority of these leases (60) are awaiting preparation of environmental assessments or environmental impact statements. There are no leases pending on USBLM lands in Oregon.

Figure 4 is a graph of the annual total amount of monies received by the Federal Government from geothermal leasing in Oregon. The graph covers the period from 1974, when leasing was initiated, to the present. Sources of income included in the graph are filing fees, rental on competitive and noncompetitive leases, and bonus bids. Income from geothermal leasing peaked in 1980 at $1,701,189 and has declined steadily since then to its present level of about $475,000.

KGRA sales

No KGRA lands were offered for bid in 1987.

In December, USFS canceled its application to withdraw 2,330 acres in the Sparks Lake-Devils Lake Recreation Area and 2,291 acres in the Bachelor Butte and Todd Lake Recreation Areas. This action opens those areas for mining. The lands had been open to leasing.

Direct-use projects

The direct use of relatively low-temperature geothermal fluids continued in 1987 at about the same level as over the last several years. Most of the activity is centered in Klamath Falls and Vale.

In Vale, the successful Oregon Trail Mushroom Company, which commenced full-scale operations in 1986, continues to operate using water from a 107 °C aquifer for heating and cooling. The operation annually produces 2.3 million kg of mushrooms that are marketed in Spokane and Seattle, Washington; Salt Lake City, Utah; and the Treasure Valley area in Idaho (Geo-Heat Center, 1987). Other users at Vale include Ag-Dryers (a grain-drying facility) and a greenhouse operation. Hawley Meat Packing is no longer using the Vale geothermal aquifer.

The Oregon Department of Water Resources completed field work for a report on the hydrogeology of the developed geothermal aquifer at Vale. The report, which is in final review, will be published during 1988.

In Klamath Falls, the city continued to wrestle with the problem of defective piping installed in the district heating system. The heating

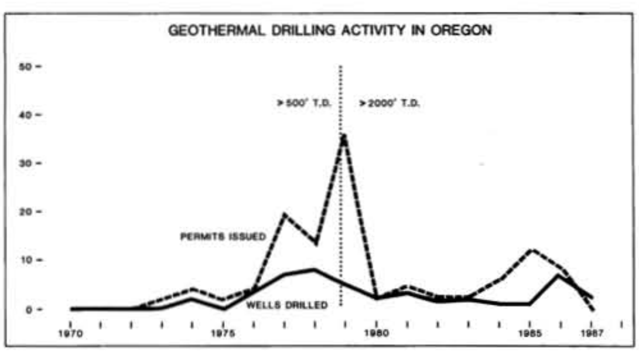

Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 2,000 ft (610 m).

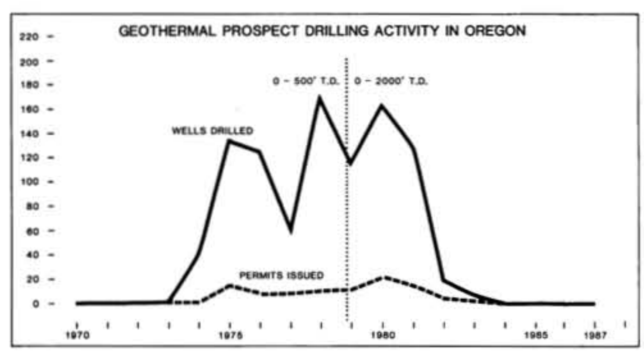

Figure 2. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth of less than 2,000 ft (610 m).

system consists of two loops. The main loop serves the downtown area. A smaller loop, constructed in 1986 with support from a U.S. Housing and Urban Development grant, serves a residential sector (Michigan Street). The residential loop is operating satisfactorily, but the downtown loop has not operated for over three years due to defective fiberglass piping. In 1987, the city completed engineering plans for the replacement of the defective piping. Actual replacement now awaits the results of legal action.

Table 1. *Active permits for geothermal drilling in 1987*

Permit no.	Operator, well, API number	Location	Status, total depth (m)
116	California Energy Co. MZI-11A 035-90014	SW¼ sec. 10 T. 31 S., R. 7½ E. Klamath County	Suspended; 413.
117	California Energy Co. MZII-1 035-90015	SE¼ sec. 13 T. 32 S., R. 6 E. Klamath County	Suspended; 148.
118	GEO* N-1 36-017-90013	SW¼ sec. 25 T. 22 S., R. 12 E. Deschutes County	Suspended; 1,387.
124	Thermal Power Co. CTGH-1 36-047-90002	SE¼ sec. 28 T. 8 S., R. 8 E. Marion County	Suspended; 1,463.
125	GEO* N-2 36-017-90018	SW¼ sec. 29 T. 21 S., R. 12 E. Deschutes County	Suspended; confidential.
126	GEO* N-3 36-017-90019	NE¼ sec. 24 T. 20 S., R. 12 E. Deschutes County	Suspended; 1,219.
127	California Energy Co. CE-NB-3 36-017-90020	NW¼ sec. 16 T. 22 S., R. 13 E. Deschutes County	Suspended; 1,325.
128	California Energy Co. CE-NB-1 36-017-90021	NW¼ sec. 16 T. 22 S., R. 12 E. Deschutes County	Canceled.
129	California Energy Co. CE-NB-4 36-017-90022	SE¼ sec. 4 T. 21 S., R. 12 E. Deschutes County	Suspended; 1,225.
130	Trendwest, Inc. Olene Gap 1 36-035-90016	NW¼ sec. 35 T. 39 S., R. 10 E. Klamath County	Canceled.
131	GEO* N-4 36-017-90023	NE¼ sec. 35 T. 21 S., R. 13 E. Deschutes County	Suspended; confidential.
132	GEO* N-5 36-017-90024	NE¼ sec. 8 T. 22 S., R. 12 E. Deschutes County	Suspended; confidential.
133	GEO* N-6 36-017-90025	SW¼ sec. 6 T. 21 S., R. 13 E. Deschutes County	Canceled.
134	GEO* N-7 36-017-90026	NE¼ sec. 3 T. 22 S., R. 14 E. Deschutes County	Canceled.

* GEO-Newberry Crater, Inc.

The Geothermal Advisory Committee in Klamath Falls is considering engineering and financial alternatives in order to bring those users of geothermal fluids who discharge effluent to the surface into compliance with the Klamath Falls Geothermal Code. The code requires that, by 1990, all geothermal waters used in the city must be reinjected. In a related action, the Oregon Institute of Technology (OIT) made plans to drill an injection well in order to eliminate surface discharge from the OIT geothermal system. The well will be drilled in the summer of 1988, and all surface discharge from the OIT campus is expected to cease in 1989.

As reported in the Geo-Heat Center *Quarterly Bulletin*, eight Klamath Falls homeowners completed a residential heating district at a cost of $148,000. The closed-loop distribution system includes a 277-m production well and a 610-m injection well along with associated pumps, heat exchangers, and piping. The production well provides approximately 80 gpm of 84 °C fluid that is reinjected at 71 °C. Water is provided to individual homes at approximately 81 °C (Geo-Heat Center, 1987).

In La Grande, Union County, the New Jersey-based company BBC Brown Boveri District Heating and Cooling, Inc., has contracted with Hot Lake Company to supply pipeline equipment and financial assistance for the recreational vehicle resort geothermal project at Hot Lake. The system will pipe 85 °C water 2,500 ft from the Hot Lake artesian well to the resort. After heating mineral baths and other buildings at the resort, the effluent will be piped a further 300 ft to proposed greenhouses. The objective of Brown Boveri District Heating and Cooling is to show how cost-effectively a small district heating system can meet heat and hot-water needs with minimum temperature loss and environmental impact. Financial assistance to Hot Lake Company will take the form of a grant to defray first-year costs of equipment that Brown Boveri is supplying to the project (Geothermal Resources Council, 1987b).

In Lakeview, the binary-cycle electrical generating station set up several years ago remains idle. The City of Lakeview terminated its agreement with Brown, Vence, and Associates, the firm that initiated the formation of a geothermal franchise in the city. The city is still interested in the development of a district heating system.

In the Bend, Redmond, Prineville, and Madras areas of central Oregon and in the Willamette Valley, there was considerable activity in 1987 in the installation of ground-water heat pumps. The Oregon

Table 2. *Geothermal leases in Oregon in 1987*

Types of leases	Numbers	Acres
Federal leases in effect:		
Noncompetitive, USFS	226	429,149.15
Noncompetitive, USBLM	10	11,121.52
KGRA, USFS	1	360.00
KGRA, USBLM	12	25,999.73
Total leases issued:		
Noncompetitive, USFS	334	651,068.55
Noncompetitive, USBLM	266	406,157.79
KGRA, USFS	8	11,924.61
KGRA, USBLM	62	118,307.85
Total leases relinquished:		
Noncompetitive, USFS	108	221,919.40
Noncompetitive, USBLM	256	395,036.27
KGRA, USFS	7	11,564.61
KGRA, USBLM	50	92,308.12
Lease applications pending	119	——

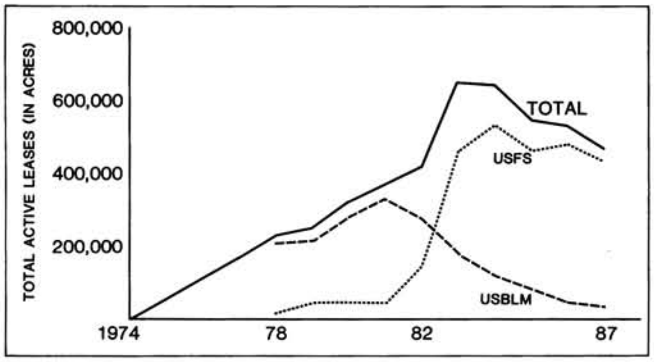

Figure 3. Active geothermal leases on Federal lands in Oregon from the inception of leasing in 1974 through December of 1987.

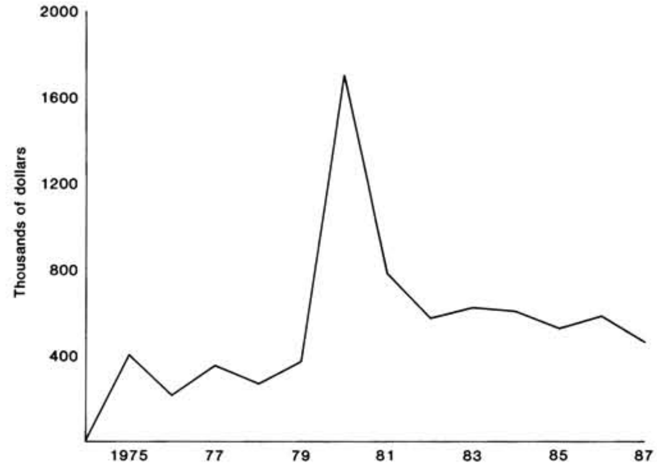

Figure 4. Federal income from geothermal leases in Oregon from the inception of leasing in 1974 to the present.

Department of Energy certified 36 residential tax credits in 1987, most of them for the installation of such systems. At the present time, a tax credit of up to $1,500 is available for each residence. The amount of the tax credit is based on energy savings, not the cost of the system.

The ownership of Jackson Hot Springs in Ashland, Oregon, has changed. At the present time, Jackson Hot Springs is still being run as a resort, though the new owners are reportedly considering other direct-use applications.

DOGAMI RESEARCH

DOGAMI geologists completed compilation of the McKenzie Bridge 15-minute quadrangle during 1987. Original field mapping was completed in 1986. Belknap, Foley, Terwilliger, and several unnamed hot springs occur in the area, which encompasses the transition zone between the High Cascades and Western Cascades near South Sister. The map will be published during 1988 (Priest and others, 1988).

Two geologic maps, each encompassing the area of a standard 15-minute quadrangle, were published in 1987. These maps cover the transition zone between the High Cascades and Western Cascades from about Breitenbush Hot Springs to just south of the junction of Highways 126 and 20. The maps were published in DOGAMI's Geological Map Series as GMS-46, *Geologic Map of the Breitenbush River Area, Linn and Marion Counties, Oregon* (Priest and others, 1987c), and GMS-47, *Geologic Map of the Crescent Mountain Area, Linn County, Oregon* (Black and others, 1987).

The geologic mapping was completed with USDOE support and was aimed at defining the geologic context of major hydrothermal systems in the Cascade Range. The three maps delineate a major zone of faulting that starts near the elbow of the North Santiam River and continues south to the headwaters of Horse Creek in the McKenzie Bridge quadrangle (Figure 5). The Western Cascades are uplifted relative to the High Cascades at this faulted boundary (Taylor, 1980; Brown and others, 1980; Priest and others, 1982, 1983). Belknap Hot Springs and adjacent unnamed hot springs are located on this fault zone (Priest and others, 1982, 1983). No major fault has been mapped through Breitenbush Hot Springs.

In 1986, DOGAMI received a grant from USDOE to complete a geologic study of the Breitenbush-Austin Hot Springs hydrothermal area, including a detailed analysis of the Thermal Power Company drill hole CTGH-1. CTGH-1 is a 1.46-km-deep hole drilled in the High Cascade Range northwest of Mount Jefferson in 1986 (Figure 5). D.R. Sherrod of the U.S. Geological Survey (USGS) is cooperating with DOGAMI to coordinate and partially write an open-file report. Geologic mapping of approximately 15 mi^2 around the site was completed by Sherrod and R.M. Conrey (Washington State University) in 1987. The final report will contain the geologic map and an analysis of cores and cuttings from the CTGH-1 hole and surrounding holes, as well as hydrothermal-alteration studies by T.E.C. Keith and K.E. Bargar of the USGS and an analysis of temperature and heat-flow data by D.D. Blackwell of Southern Methodist University. An open-file report that synthesizes the data in terms of a geothermal model for the Breitenbush-Olallie Butte area will be published in October 1988.

In July 1987, DOGAMI staff met in Bend, Oregon, with representatives of USFS, USBLM, and interested scientists to select potential drill sites for the Program for Scientific Drilling in the Cascades (PSDC). The main purpose of the drilling program is to investigate the thermal regime of the Cascade Range volcanic axis. Secondary objectives are to examine the rate and composition of volcanism occurring in the central portion of the Cascades during the last several million years. Three sites were identified near Santiam Pass for the first stage of drilling. Two of the sites are near Blue Lake, and the third is on Cache Creek (Figure 6). Drilling is expected to begin in late summer or early fall of 1988 at one of the sites. The proposed depth for this initial stage of drilling is 2,100 ft. Details of the PSDC plan were described in an open-file report published by DOGAMI in 1987 (Priest and others, 1987a). A nontechnical summary of the plan is also available upon request.

In 1987, DOGAMI published four other maps of interest to the geothermal community. Three maps by G.A. Smith (University of New Mexico) provide detailed 1:24,000-scale coverage of the Deschutes Basin (Smith, 1987a-c). The fourth map, published at the same scale, is E.M. Taylor's map of the northwest quarter of the Broken Top 15-minute quadrangle (Taylor, 1987; Figure 5).

ACTIVITIES OF OREGON WATER RESOURCES DEPARTMENT

The Oregon Water Resources Department (OWRD) continued its low-temperature geothermal program that includes monitoring of the resources in Vale, the Klamath Falls area, and Lakeview.

A report on the hydrogeology of the developed geothermal aquifer at Vale has been completed and is in final review. The report describes the geology and hydrology of the developed geothermal aquifer and documents some of the temperature and pressure changes that have resulted from development.

Monitoring of the geothermal aquifer in Klamath Falls shows that water levels have been declining at a rate of approximately 0.3 m per year since about 1975. In 1985, the City of Klamath Falls passed the Geothermal Management Act in order to eliminate, by 1990, the wasteful discharge of geothermal water that is presumably causing the decline. In November 1987, the Oregon Water Resources Commission was presented with an OWRD staff report describing the Klamath Falls decline and its implications. The report recommended

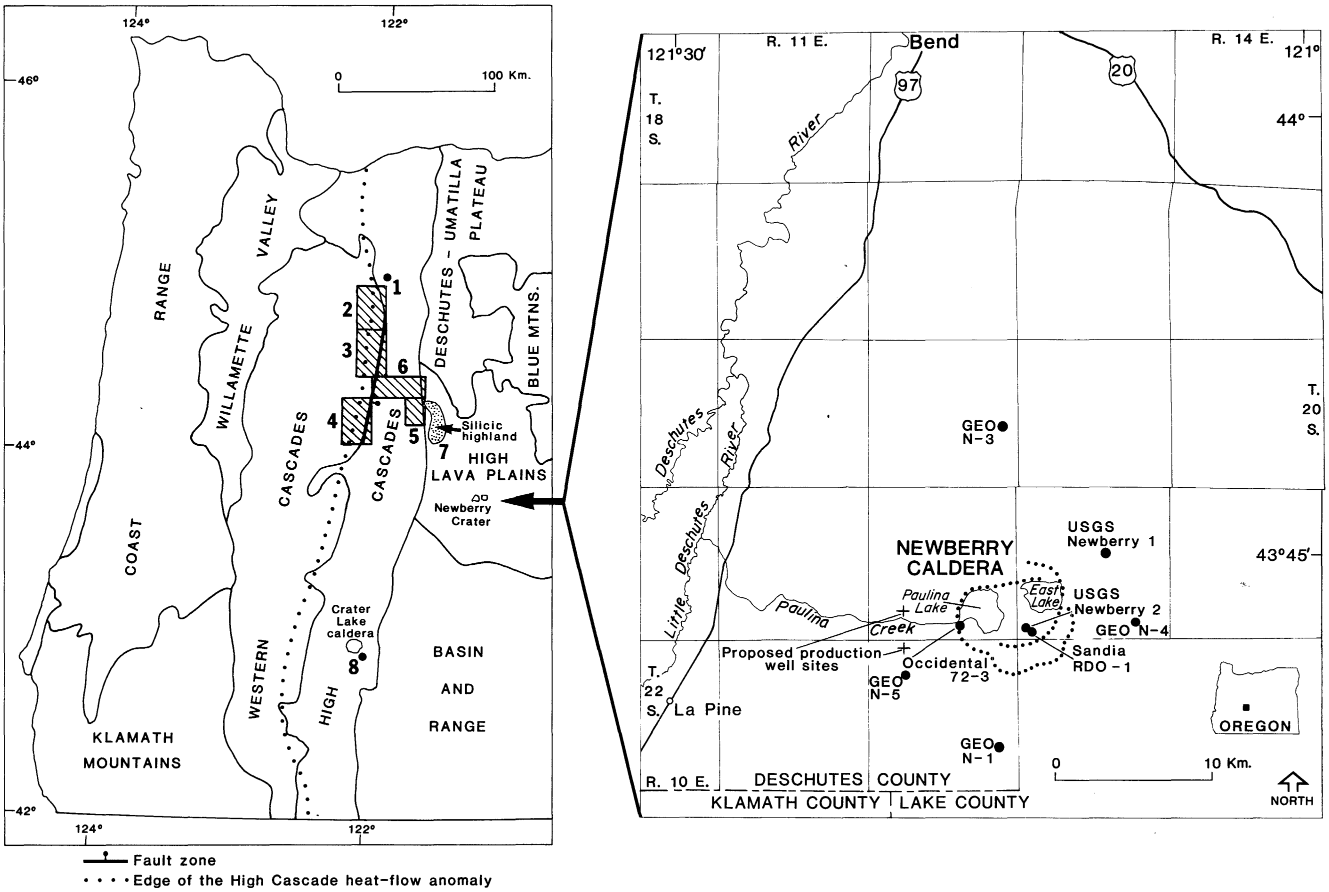

Figure 5. Physiographic provinces of western Oregon (after Dicken, 1950) showing major areas of geothermal activity discussed in text. 1. Location of Thermal Power drill hole CTGH-1. 2. Breitenbush River map area. 3. Crescent Mountain map area. 4. McKenzie Bridge quadrangle. 5. NW Broken Top quadrangle. 6. Santiam Pass study area. 7. Silicic highland. 8. Location of CECI drill hole MZI-11A. Edge of High Cascade heat-flow anomaly after Black and others (1983).

Inset map of Newberry caldera area shows locations of temperature-gradient holes discussed in text and GEO permitted production well sites. Dotted lines show ring-fractures of Newberry caldera.

that the OWRD continue to closely monitor conditions in the geothermal aquifer and track progress toward the elimination of wasteful discharge. If the decline continues after 1990, the OWRD will evaluate the situation in Klamath Falls and may consider administrative action to stabilize water levels.

Water levels fluctuate yearly in Klamath Falls, with lowest levels occurring during the peak heating season in February. Water levels in February 1988 did not show any decline relative to 1987, probably due to the mild weather and resultant decreased heating demand.

The responsibility for the OWRD low-temperature geothermal program has been recently transferred from Marshall W. Gannett, who took over the program in 1984, to Susan V. Hartford.

ACTIVITIES OF OREGON DEPARTMENT OF ENERGY

In 1987, geothermal activities of the Oregon Department of Energy (ODOE) focused on research and support for other agencies. ODOE, in cooperation with the Washington State Energy Office, continued to perform economic research into new geothermal power plants for the Bonneville Power Administration (BPA). Research into direct-use district heating systems was completed, and a paper titled "District Heating in Oregon" was published by ODOE in July 1987.

ODOE continues to respond to inquiries on geothermal energy development from the public. Over 130 such responses were provided in 1987. ODOE also certifies geothermal tax credits. Thirty-six residential and seven business tax credits were certified in 1987. ODOE continues to provide leadership in the Pacific Northwest Section of the Geothermal Resources Council (GRC). Finally, ODOE reviewed and commented on the geothermal-energy aspects of the remaining National Forest Draft Management Plans. All of these plans have now been completed in draft form.

GEO-HEAT CENTER, OREGON INSTITUTE OF TECHNOLOGY

The Geo-Heat Center at OIT specializes in assisting in the development of low-temperature (<90 °C) and moderate-temperature (90-150 °C) geothermal applications for direct use. The Center is under contract with USDOE to provide geothermal services to State and Federal agencies who receive requests from engineering consultants, planners, and developers for development assistance on direct-use projects. The assistance can range from answering technical questions and simple consultations on methods, equipment, and applications to providing feasibility studies. The Geo-Heat Center has published over 70 such feasibility studies, which are available as examples. The project period is slated to run through the end of 1992.

In 1987, the Geo-Heat Center started to assemble information on the original design and subsequent performance of a selected group of geothermal district heating systems that have logged at least three years of operation. Specific areas of investigation are customer connect time, disposal, and equipment type and construction materials for production pumps and transmission piping. The operational performance of equipment in each of these areas will be described and will serve as a reference for designers of new systems and operators of existing systems. The report will be published in 1988.

The Geo-Heat Center continues to evaluate the performance of downhole heat exchangers. It is currently gathering information on design, applications, and research throughout the world. The information will be available in late 1988.

The Geo-Heat Center aided OIT in making plans to drill an injection well to eliminate surface discharge from its geothermal system. The OIT geothermal system has utilized surface discharge of spent geothermal fluids since its inception. The well will be drilled in the summer of 1988, and all surface discharge from the OIT campus is expected to cease in 1989.

The Geo-Heat Center continues to be involved in the evaluation of the Klamath Falls geothermal aquifer. Its staff plays an active role on the Klamath Falls Geothermal Advisory Committee. The Center continues to publish the Geo-Heat Center *Quarterly Bulletin*, which has been in circulation since 1975.

RELEVANT RESEARCH BY OREGON STATE UNIVERSITY

E.M. Taylor of Oregon State University (OSU) completed a report on the geology of the northwest quarter of the Broken Top quadrangle. The paper was published in 1987 as DOGAMI Special Paper 21 (Taylor, 1987). Taylor also aided in the compilation of the geology of the McKenzie Bridge quadrangle, which will be published in 1988 in DOGAMI's Geological Map Series as Map GMS-48 (Priest and others, 1988).

B.E. Hill, a doctoral candidate at OSU, is continuing his work on Quaternary ash flows in the Bend area (Hill, 1985) and the silicic highland west of Bend (Figure 5). As detailed in last year's geothermal summary (Priest and others, 1987b), new data indicate that the Bend Pumice/Tumalo Tuff air-fall/ash-flow sequence may be considerably younger than previously supposed (Sarna-Wojcicki and others, 1987). Hill has also acquired data that support a silicic highland source for the ash flows (Hill, 1985). In an abstract prepared for the Geological Society of America (GSA) annual meeting in 1988, Hill proposes that the silicic highland be formally named the Tumalo Volcanic Center (B.E. Hill, written communication, 1988).

J. Dymond and R.W. Collier of the OSU College of Oceanography started investigations at Crater Lake during the summer of 1987. They are trying to determine whether hot springs exist on the floor of the lake. In September 1987, they used an unmanned submersible in the lake in an attempt to directly observe the supposed springs. Results were equivocal. Further dives in a manned submersible were planned for 1988.

ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY

The USGS was involved in several geothermal-related projects in 1987. Compilations of the geologic map of the State of Oregon by G.W. Walker and N.S. MacLeod and the Salem 1° by 2° sheet by Walker and R.A. Duncan were completed.

D.R. Sherrod continued his work on a compilation of the geology of the Oregon Cascade Range. The final product of this project, which is headed by J.G. Smith, will be a geologic map of the entire Cascade Range in the United States. The map scale will be 1:500,000. Quaternary volcanic rocks are emphasized on the maps because of their importance to geothermal investigations. These rocks are split into five age divisions and four compositional divisions. Western Cascades rocks, which are not so well known as the younger rocks, are shown in less detail (Sherrod, 1987).

In addition to his compilation of the geology of the Oregon Cascades, Sherrod is coordinating a study on the Thermal Power Company CTGH-1 drill hole for DOGAMI. The study is funded by USDOE. Sherrod and R.M. Conrey (Washington State University) completed mapping of approximately 15 mi^2 around the drill hole in 1987. The report is scheduled for publication in the fall of 1988. In addition to his work on the Thermal Power hole for DOGAMI, Conrey continued his detailed geologic mapping at Mount Jefferson.

T.E.C. Keith and K.E. Bargar continued their hydrothermal-alteration studies of holes drilled under the USDOE cost-share program. They will be contributors to the Thermal Power report.

D.V. Fitterman is editing a special issue of the *Journal of Geophysical Research* on Newberry volcano. The issue will include articles on geology, hydrothermal alteration, transient electromagnetic soundings, magnetotelluric soundings, resistivity, high-resolution seismic imaging, gravity, and magnetics (Muffler, 1987).

A.M. Sarna-Wojcicki was main author of a summary of tephra-correlation studies that are relevant to the geothermal potential of the Cascades in the Three Sisters-Bend area (Sarna-Wojcicki and others, 1987). See Priest and others (1987b) for a detailed discussion of these data and the geothermal potential of the silicic highland (Figure 5).

The USGS Water Resources Division completed three years of intensive work in the Cascade Range. The program included NaCl surveys, stable-isotope studies, and water-chemistry and temperature-gradient work in the central Oregon Cascades between Mount Hood and the Three Sisters. The data will be summarized in an open-file report to be released in the fall of 1988. The Water Resources Division intends to drill a series of six shallow temperature-gradient holes in the Cascade Range in 1988 to fill in gaps in the existing heat-flow data base (S. Ingebritson, personal communication, 1988).

In May 1987, R.L. Christiansen replaced L.J.P. Muffler as Chief of the Branch of Igneous and Geothermal Processes and Coordinator of the Geothermal Research Program. Muffler will return to research activities in geothermal energy.

ACTIONS OF REGULATORY AGENCIES CONCERNING GEOTHERMAL EXPLORATION

The Oregon Board of Geologists Examiners ruled that individuals practicing in the fields of hydrogeology and geothermal geology do not have to be certified by the Board as engineering geologists. It was felt that these fields require a broad range of geologic expertise that is not limited to the domain of engineering geology. Persons practicing in these fields do, however, have to be registered geologists and must adhere to the Code of Professional Conduct (Chapter 809 of Oregon Administrative Rules).

Two wells of California Energy Company, Inc., (CECI) near Crater Lake have been placed in suspended status by DOGAMI and USBLM. CECI requested the suspension while the company responds to the Sierra Club appeal of the USBLM ruling to the Board of Land Appeals. USBLM had ruled to grant CECI permission to drill the two temperature-gradient holes to 5,500 ft with total loss of circulation. The situation at Crater Lake is discussed in detail in a later section.

In early 1987, BPA announced its objectives to implement the 1986 Power Plan developed by the Pacific Northwest Power Planning Council. In the 1983 Power Plan, the Council had recommended that BPA develop a 10-MWe-capacity demonstration program. It was hoped that the demonstration program would encourage confirmation of the geothermal resource in the Pacific Northwest. The new 1986 power plan focused on resource confirmation rather than a demonstration plant. BPA's objectives to implement the 1986 plan are threefold:

1. Design a confirmation program that will result in the confirmation of a single-site, environmentally acceptable geothermal resource capable of supporting 100 MWe for 30 years.

2. Provide assurance that the electrical power generated from the resource will be made available to the region at competitive prices when it is needed in the future.

3. Complete the design of the confirmation program by the end of fiscal year 1988 (Geothermal Resources Council, 1987a).

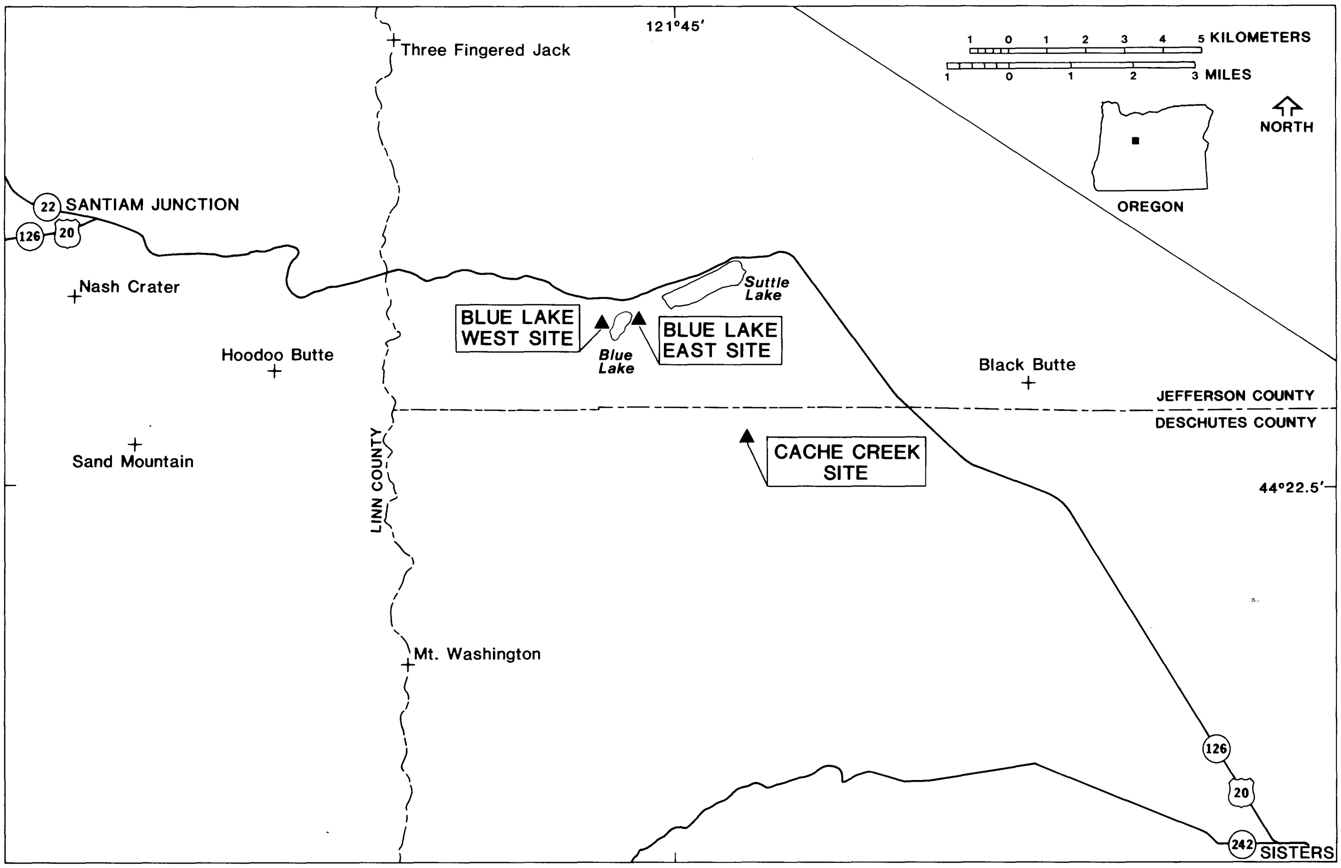

Figure 6. Location of potential PSDC drill sites near Santiam Pass, Oregon.

NEWBERRY VOLCANO

There was moderate activity at Newberry volcano during 1987. GEO-Newberry Crater, Inc., (GEO) drilled two holes: one on the southwest flank (Hole GEO N-5, Figure 5; Table 1) and the other on the east flank of the volcano (Hole GEO N-4, Figure 5; Table 1). Both holes were wireline-drilled temperature-gradient tests permitted to 5,000 ft.

GEO also announced plans to drill a small production well on one flank of the volcano in 1988. DOGAMI in early 1988 granted permits for two sites: SE¼ sec. 29, T. 21 S., R. 12 E., and NE¼ sec. 5, T. 22 S., R. 12 E. (Figure 5). As of mid-June 1988, the Environmental Assessment for the drilling had been approved by USBLM, and the thirty-day appeal period had passed with no appeals filed. It appears at this time, however, that drilling operations on Newberry will not begin until 1989.

The period of confidentiality on data from a hole drilled on the west flank of Newberry volcano ended in late 1987; the data are therefore now available to the public. The hole was spudded in September 1983 by Occidental Geothermal, Inc., in sec. 3, T. 22 S., R. 12 E. (Occidental 72-3, Figure 5). The hole was drilled to a total depth of 3,504 ft in the fall of 1983. The hole was reentered in the fall of 1984 and deepened to 4,501 ft. Information from only that portion of the hole above 3,504 ft is currently available. Data on the remainder of the hole will become public in the fall of 1988. The operator of record is now Santa Fe Geothermal, Inc., of Bakersfield, California.

The temperature-depth curve for hole 72-3 is reproduced in Figure 7, along with the other available temperature-depth curves from deep holes drilled at Newberry Crater. The hole was logged in October 1985, approximately one year after the completion of drilling operations in 1984. The temperature-depth curve can be divided into two parts. The upper part is essentially isothermal to a depth of approximately 470 m. This section of the curve represents the "rain curtain" typical of the young volcanic rocks of the High Cascade Range and Newberry Crater. The lower part of the curve is linear and represents conductive heat flow. The gradient for this portion of the hole is 138 °C/km. The bottom-hole temperature (at 1,060 m) is 114 °C.

In all, data from six deep holes at Newberry are now available. Temperature-depth profiles from two holes inside the caldera (USGS Newberry 2 and Sandia Laboratories RDO-1, Figures 5 and 7) have isothermal gradients to depths of approximately 275 m. On the flanks of the volcano, data from four holes (USGS Newberry 1, Occidental 72-3, and GEO N-1 and N-3, Figures 5 and 7) indicate that the "rain curtain" extends to depths of approximately 450-550 m.

CRATER LAKE

In November of 1986, California Energy Company, Inc., (CECI) suspended drilling on its MZI-11A hole on the southeast flank of Mount Mazama. Drilling was ordered suspended by USBLM because the loss of circulation encountered in the hole was a violation of the drilling permit. CECI requested that the Environmental Assessment for the Crater Lake drilling operations, which contained stipulations prohibiting drilling without circulation, be changed to allow drilling with total loss of circulation (a standard procedure in the porous volcanic rocks of the High Cascade Range). USBLM subsequently ruled to grant CECI permission to drill without circulation. The Sierra Club then filed an appeal of the USBLM ruling to the Board of Land Appeals in Arlington, Virginia. The appeal is currently under review. A ruling is expected to take one to two years. At company request, pending outcome of the appeal, CECI's two wells near Crater Lake have been placed in suspended status by DOGAMI, and the leases have been placed in suspended status by USBLM.

Table 3. *Mazama Geothermal Unit chronology*

1/84: California Energy Company, Inc. (CECI) enters into two geothermal unit agreements with the U.S. Bureau of Land Management (USBLM) on Federal geothermal leases it owns in the Winema National Forest. Mazama Unit I is east of Crater Lake National Park and contains 80,483.49 acres. Mazama Unit II is south of Crater Lake National Park and contains 18,682.66 acres.
2/84: CECI submits detailed plan of operation for drilling temperature-gradient holes at the Mazama Units I and II.
3/84: USBLM submits an Environmental Assessment of the proposed drilling operations for temperature-gradient holes in the two Mazama units. Comments are solicited.
12/84: USBLM and the USDA Forest Service (USFS) grant CECI permission to drill up to four temperature-gradient holes in the Mazama Units I and II.
5/85: CECI applies for drilling permits for four temperature-gradient holes in the Mazama Units I and II. USBLM and the Oregon Department of Geology and Mineral Industries (DOGAMI) approve the permit applications.
6/85: DOGAMI Governing Board grants a CECI request to allow the extension of the CECI drilling permits until 6/87.
9/86: CECI commences drilling operations on temperature-gradient hole MZI-11A, located in Mazama Unit I. The hole is cost-shared with the U.S. Department of Energy (USDOE).
11/86: CECI commences drilling operations on temperature-gradient hole MZII-1, located in Mazama Unit II. The hole is cost-shared with USDOE.
11/86: The two drilling operations are ordered to be suspended by USBLM due to loss of circulation while drilling, which is a violation of the drilling permit. Temporary suspension status is granted to CECI by USBLM. The MZI-11A hole is at a total depth of 1,354 ft with a bottom-hole temperature of 107 °C. The MZII-1 hole is at a total depth of 485 ft with surface casing set.
11/86: CECI requests that the USBLM grant approval of permit modification to complete the drilling of the MZI-11A and MZII-1 temperature-gradient holes to 5,500 ft without maintaining circulation of the drilling fluids to the surface.
2/87: *Federal Register* published regarding protection of significant thermal features within the National Park System. Crater Lake is included on the list of significant thermal features proposed for study on the basis of possible hot springs in the floor of the lake.
2/87: Crater Lake Technical Workshop held in Portland, Oregon, to discuss the *Federal Register*, hydrology, and potential impact of drilling temperature-gradient holes in Mazama Units I and II. Workshop is sponsored by the Pacific Northwest Section of the Geothermal Resources Council and is attended by representatives from DOGAMI, the U.S. Geological Survey (USGS), Portland State University (PSU), Oregon State University (OSU), CECI, USBLM, USFS, and numerous other State and Federal governmental, academic, industry, and environmental organizations.
5/87: USBLM submits Supplemental Environmental Assessment to the 3/84 Environmental Assessment regarding CECI's 11/86 request for permit modification.
6/87: DOGAMI cancels the two remaining CECI Mazama Unit drilling permits due to expiration of the permits. Permits for the MZI-11A and MZII-1 holes remain in suspended status.
7/87: USBLM rules to implement the Supplemental Environmental Assessment. That is to grant CECI permission to drill the temperature-gradient holes to a depth of 5,500 ft with fluid loss to the subsurface. USBLM finds that the proposed action of drilling temperature-gradient holes would not have a significant impact on the environment.
8/87: Final list of National Parks with significant thermal features is published in the *Federal Register*. It is decided that there are insufficient data to warrant the inclusion of Crater Lake National Park in the final list. A decision on Crater Lake National Park is deferred until more information is available.
Fall/87: USGS releases Open-File Report 87-587 on the chemical analysis of waters from Crater Lake and nearby springs. The authors find that the data are permissive of hot spring input into the floor of the lake, but are not conclusive. The data did not permit the assessment of amount, temperature, or composition of any fluids that might be entering the lake (Thompson and others, 1987).
9/87: The Sierra Club files an appeal of the USBLM decision of 7/87 to the Board of Land Appeals, Arlington, Virginia. The appeal is currently under review.
9/87: The National Park Service deploys an unmanned submersible in Crater Lake in an attempt to gather direct physical evidence of the existence of hot springs in the floor of the lake. The deployment is in support of research in progress by J. Dymond and R.W. Collier of OSU.
10/87: CECI must respond to the Sierra Club appeal of the USBLM ruling to the Board of Land Appeals. It normally takes one to two years for the Board to respond with a ruling. During this time, the two Mazama Unit wells may remain in suspended status.
10/87: E.A. Sammel (USGS, retired) and S. Benson (Lawrence Berkely Laboratory) publish their findings in the *Transactions* of the Geothermal Resources Council annual meeting. They interpret the data to indicate that geothermal drilling will neither pollute the lake nor affect the hydrologic regime in the vicinity of the caldera.
1/88: Senator Mark Hatfield of Oregon puts forth an amendment before the Senate Energy and Natural Resources Committee that would establish Crater Lake as a significant thermal feature. The amendment does not prohibit geothermal drilling, but allows the Secretary of the Interior to withdraw lands from geothermal leasing, if geothermal development appears likely to damage the lake. It also requires the Secretary to halt or restrict ongoing geothermal activity that appears likely to cause damage. The legislation was approved by the Committee.
2/88: In a letter to the Secretary of the Interior, Oregon Governor Neil Goldschmidt urges the Department of the Interior to halt further geothermal leasing on national forest lands around Crater Lake National Park. The Governor is concerned that geothermal development on the flanks of the Crater Lake caldera would adversely affect the beauty and serenity of the park.
2/88: The DOGAMI Governing Board grants suspended status to the MZI-11A and MZII-1 temperature-gradient wells through August 31, 1988. USBLM has previously granted suspended status to the leases through the same date. The suspension was granted at CECI request.
2/88: Draft report titled "Studies of Hydrothermal Processes in Crater Lake: A Report of Field Studies Conducted in 1987 for Crater Lake National Park," by J. Dymond and R.W. Collier of OSU is released to the National Park Service.
3/88: USBLM releases a review of the Collier and Dymond report, concluding that there is still a lack of definitive evidence regarding the presence or absence of hot springs in the floor of the lake.
5/88: Senator Hatfield's amendment to add Crater Lake to the list of significant thermal features passes the Senate.
5/88: Senator Hatfield's amendment to add Crater Lake to the list of significant thermal features clears the House Interior Committee on a voice vote. Tony Coehlo of California offers a provision that would allow sites to be removed from the list if conclusive evidence shows no thermal feature would be harmed by leasing. A compromise places Crater Lake on the protected list, but requires the Secretary of the Interior to report to Congress in six months as to whether or not significant thermal features actually exist in Crater Lake National Park.
6/88: The Pacific Division of the American Association for the Advancement of Science holds a special session on "The Clarity of Crater Lake, Oregon. An Ecosystem Study." The session includes talks by 16 speakers active in research at the lake. Subjects covered include geology, sedimentology, chemistry, clarity, color studies, climatology, and biology.

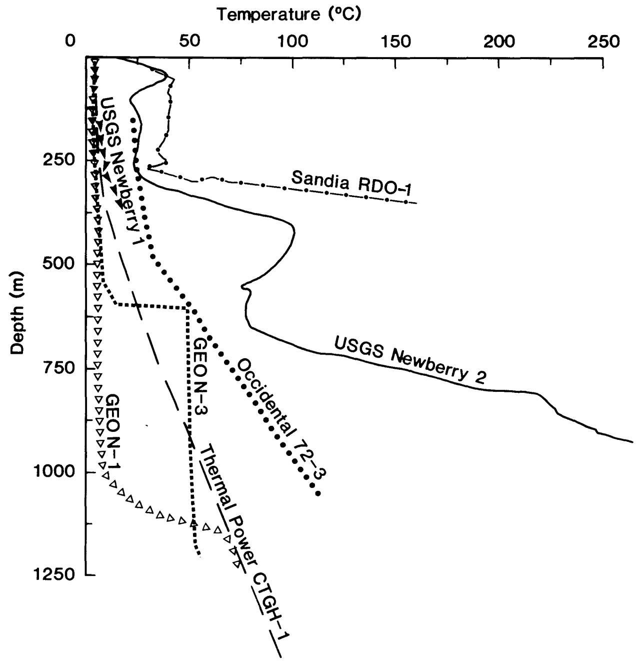

Figure 7. Temperature-depth curves for Newberry drill holes and Thermal Power CTGH-1.

In deciding to grant CECI permission to drill without circulation, USBLM hired as a consultant E.A. Sammel (USGS, retired). Sammel and S. Benson (Lawrence Berkeley Laboratory, funded by USDOE) collaborated on a study of the ground-water flow system in the vicinity of Crater Lake to examine the potential effects of introducing drilling mud into this flow system. In a paper published in 1987, Sammel and Benson stated that, "Based on our calculations that show the regional flow of ground water will oppose the flow of drilling mud toward the lake, and based on our volumetric estimate of drilling mud migration, our study concludes that drilling without returns will not pollute Crater Lake, nor will it affect the hydrologic regime in the immediate vicinity of the Crater Lake caldera" (Sammel and Benson, 1987).

The USBLM, in response to an October 15, 1986, Congressional order, suspended geothermal leasing on Federal lands (see Section 115(2)(a) of the October 15, 1986, *Congressional Record*). The order gave the Secretary of the Interior 120 days to publish a proposed list of significant thermal features in the National Park System. After publication of the proposed list, the Secretary was given 60 days to evaluate public comment and send a final list to the Committee on Energy and Natural Resources of the Senate and the Committee on Interior and Insular Affairs of the House of Representatives. The proposed list was published on February 13, 1987, in the *Federal Register* (Federal Register, 1987a). It contained references to the heat-flow anomalies found by the USGS on the floor of Crater Lake (Williams and von Herzen, 1983). The Department of the Interior was faced with the decision as to whether these heat-flow anomalies qualified as "significant thermal features" under the guidelines of the Congressional order. The final list was published in the *Federal Register* in August 1987. Crater Lake was not included on the final list. It was decided to defer a decision on Crater Lake pending further studies.

In February 1987, the Pacific Northwest Section of the Geothermal Resources Council held a special symposium on Crater Lake. Topics of discussion included geology, Crater Lake heat flow, the presence or absence of hot springs in the floor of the lake, the interpretation of lake geochemistry, possible causes of loss of lake clarity, and the effects of drilling outside the Park boundary on hydrothermal convection systems beneath the lake.

In the summer of 1987, J. Dymond and R.W. Collier of OSU commenced studies aimed at establishing the presence or absence of hot springs in the floor of Crater Lake. The studies culminated in September when the National Park Service deployed an unmanned submarine in Crater Lake. The results were equivocal.

Table 3 is a chronology of events at the Mazama geothermal unit since 1984, when CECI entered into unit agreements with USBLM.

ACKNOWLEDGMENTS

This paper could not have been written without the cooperation of numerous individuals in government and industry. Jacki Clark of USBLM provided the Federal leasing data. Jack Feuer, Dennis Simontacchi, and Dennis Davis of USBLM and Bob Fujimoto of USFS provided much useful information on regulatory issues. Dennis Olmstead and Dan Wermiel of DOGAMI provided the data on drilling permits. Alex Sifford of ODOE and Marshall Gannett of OWRD provided the information on their agencies' activities for the year. Paul Lienau of OIT provided much of the information on direct-use projects around the state. David Sherrod of the USGS and Steve Ingebritson of USGS Water Resources provided accounts of USGS activities in Oregon in 1987. Joe LaFleur of California Energy and Cliff Walke of GEO provided activity accounts of their respective companies in Oregon at Crater Lake and Newberry Crater.

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*(Continued on page 116, **Geothermal**)*

New guides for central Oregon published

ROADSIDE GUIDE TO THE GEOLOGY OF NEWBERRY VOLCANO, by R.A. Jensen, Bend, Oregon, 1988, 75 p., $7.95 (postage paid).

The area of Newberry volcano, the dominant geologic feature of the northwestern end of Oregon's High Lava Plains physiographic province, is an ideal laboratory for visitors who are interested in volcanic features. Located approximately 25 mi south of Bend, the Newberry area contains nearly every conceivable variety of volcanic rock produced by a volcano whose eruptive history spans more than half a million years. Jensen's guidebook brings together the available information on Newberry volcano in a form useful to any visitor interested in the geology or history of the area.

As a roadside guide, the book presents five major tours, one circling the entire area (a round-trip of almost 150 mi, departing from and returning to Bend) and four tours dissecting the area, mainly from Newberry Crater to the south. Most tours include some side trips that lead to points of particular interest. All tours and side trips are tied in with the "Circle Newberry Tour" by cross-references.

The description of observable features along the trip routes is presented in great detail and accompanied by many helpful illustrations, maps, and tables. Thus, for instance, the initial map of the entire area shows not only all tour roads but also their quality, from paved roads to unmaintained dirt roads. An index map shows all 7½-minute quadrangles that make up the Newberry area, so that visitors can equip themselves with the appropriate detailed USGS topographic quadrangle maps for their trips. Toward the end of the book, three "viewpoint tables" explain practically all visible features that can be seen from the tops of Pilot Butte, Lava Butte, and Paulina Peak.

It almost goes without saying that such a thorough guide includes a general discussion of the geology, a glossary of geologic terms, and reference lists for the geology of volcanic phenomena in general as well as the history and geology of the Newberry area in particular.

The book is available from CenOreGeoPub, 20180 Briggs Road, Bend, Oregon 97701, and at the Lava Lands Visitor Center near Bend as well as various bookstores in central Oregon.

CENTRAL OREGON CAVES, by Charlie and Jo Larson. ABC Printing and Publishing, Vancouver, Washington, 1987, 44 p., $3.85.

For accomplished cavers as well as for people who just want to learn something about caves, especially lava tubes, this book (size approximately 9x6 in.) provides an introduction to the cave-rich central Oregon area around Bend.

Following a general introduction about the formation and features of lava tubes and similar caves, twenty caves or groups of caves are described by the authors. Most of the caves are located in the area south of Bend, on the flanks of Newberry volcano; a few are farther away, near Redmond and in the High Cascades to the west. Most descriptions are accompanied by photographs, maps, and cross sections of the caves.

The descriptions touch lightly on all aspects of interest—access, geology, special warnings for explorers, historical features—without giving away too much, thus stimulating the reader's appetite for learning more (wouldn't you like to find out, for instance, what's in the "Grim Reminder Room" of the South Ice Cave?).

For the visitor who is new to, but interested in, caving as a recreational activity, the authors provide introductory information, such as debunking myths about caves, preparations for entering caves, and safe and considerate conduct in them.

The book concludes with a glossary explaining some technical terms, a short list of further reading on caves, and information about the National Speleological Society, to which most local caving clubs belong.

LAVA RIVER CAVE, by Charlie and Jo Larson. ABC Printing and Publishing, Vancouver, Washington, 1987, 24 p., $2.85.

Lava River Cave was a state park from 1926 to 1981, when it became part of the Deschutes National Forest, and is now managed as a day-use recreational site.

Similar in format and style to the booklet described above, this one deals in extensive detail with the longest, most accessible, and most popular cave of the Bend area—"a lava tube of world-class dimensions."

The guide divides the approximately 1 mi of lava tube into five sections, describing, mapping, and illustrating each in considerable detail. It includes occasional discourses on such features as the air movement, the accumulations of "sand," or the erosive action of "ice wedging" in the cave.

Both booklets are excellent introductions and guides for the visitor to central Oregon. They are available from the publisher, ABC Printing, 13318 NE 12th Avenue, Vancouver, WA 98685. For each title, the prices given above include $0.90 for postage. □

GPO offers books in Oregon

The U.S. Government Printing Office (GPO) has opened a bookstore for its publications in Portland, the latest of about two dozen stores throughout the Nation.

This new outlet for products of the GPO offers book publications (also some maps and posters) produced by various Federal agencies and released by them for sale through the GPO. On opening day, we found, for example, publications related to earth science and mineral industry from such agencies as the USDA Forest Service, NASA, the Office of Surface Mining Reclamation, the Office of Technology Assessment, and the U.S. Geological Survey (Survey maps are not offered here, but, e.g., a Professional Paper on Mount St. Helens and an open-file report on ice volumes of Cascade volcanoes). Most of the titles offered on the store's shelves are intended for nontechnical use and the general public. However, the bookstore's management is flexibly oriented toward the public's demand for publications and will update its stock periodically according to that demand.

In addition, the bookstore offers its services not only by presenting publications in the store but also by making available a current catalog of available publications and a subject-oriented bibliography and index of all GPO publications, so that customers may order these materials through the bookstore. Both the catalog and the subject indexes are available upon request. They may prove to be a convenient way for many Oregonians to gain access to publications that are not easily obtained from regular bookstores.

The new facility is located at 1305 SW First Avenue, Portland, OR 97201-5801, phone (503) 221-6217, and is open Monday through Friday from 9:00 a.m. to 5:00 p.m. □

(MLR, continued from page 98)

4. Permit boundary line. New rules require the identification of a permit boundary line that describes the area within which mining activities are permitted. Buffer strips, processing areas, spoil sites, and future mining areas are to be located within the permit boundary. For more specific information, operators should contact the Department MLR office.

5. Fee increases scheduled. The Department has scheduled to raise fees to the statutory maximum for all renewals and new applications, the change to be effective October 1, 1988. Renewal fees will be increased from $375 to $385 per year, fees on new applications from $500 to $535 per year. Comments and suggestions should be submitted to the MLR office. □

OIL AND GAS NEWS

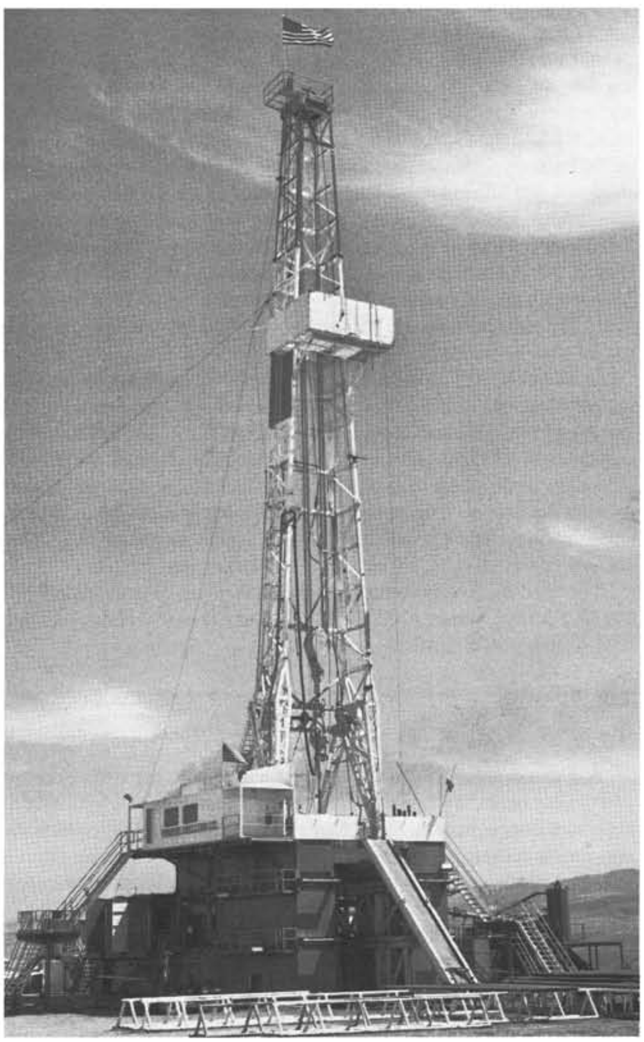
Mist Gas Field: Gas storage

Oregon Natural Development continues its program of four injection wells and one monitor well this season. These wells will complete the drilling portion of the storage project. Three injection wells have been drilled and completed: IW 330-3, IW 23B-3, and IW 42C-10. The remaining wells this year will be IW 22D-10 and OM 43B-10.

The company is concurrently making extensive modifications and additions to the gas treatment and compressor plant at the storage site. In addition, a new 50-mi pipeline is planned to carry gas from Mist to the Portland area. This project is scheduled for 1989.

ARCO continues exploration at Mist

ARCO has pursued a busy exploration schedule in the field, mainly south of State Highways 202 and 47. So far, the following wells have been drilled: CC 42-8-54, CC 44-27-65, LF 32-20-65, LF 32-20-65R, CFI 34-1-55, and Johnson 44-19-65. Of these, three have been completed as producers: CC 42-8-54, CC 44-27-65, and CFI 34-1-55. Flow rates will be released by ARCO at the end of the season. Wells LF 32-20-65 and Johnson 44-19-65 were plugged and abandoned, and LF 32-20-65R is now being drilled as a replacement for LF 32-20-65, which did not reach its proposed total depth.



ARCO well Hanna 1 in Morrow County

Morrow County wildcat drilling

ARCO continues to drill its Morrow County well, Hanna 1. The well, 6 mi from Heppner, was spudded June 7, and has a proposed total depth of 9,000 ft. No information has been released from the well. The well should be at total depth by November of this year.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
411	ARCO Hamlin 33-17-65 36-009-00245	SE¼ sec. 17 T. 6 N., R. 5 W. Columbia County	Location, 2,835.
412	ARCO Longview Fibre 32-20-65R 36-009-00246	NE¼ sec. 20 T. 6 N., R. 5 W. Columbia County	Location, 3,100.

□

(Geothermal, continued from page 114)

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USGS, USBM open joint minerals information office

A new mineral and earth science information center has been opened in Washington, D.C., as a cooperative venture of the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). The new Minerals Information Office will provide greatly expanded services from the Nation's largest pool of earth science information sources and public mineral scientists, both to the general public and to users from government, industry, and the scientific community.

The new Minerals Information Office is located next door to the expanded and renamed USGS Earth Science Information Center (formerly Public Inquiries Office) in the 2600 corridor at the E Street entrance of the main Interior Department Building, 18th and E Streets, NW.

Among the services the new offices offer to users are the following:

Availability of minerals experts from both USBM and USGS to provide access to all of the hundreds of thousands of reports on mineral-related subjects that have been published by the two Interior Department agencies over the last century.

Sale of and access to more than 70,000 topographic maps of the Nation and more than 17,000 different maps and reports on earth science subjects—earthquakes, volcanoes, floods, and fossils, to name a few—that have been published by the USGS.

Updated listings of current reports and maps prepared by the two agencies—about 10,000 new titles a year—plus computerized listings of 127,000 titles that are part of the USGS library, largest earth science library in the western world.

The largest statistics on worldwide mineral production and use, compiled by USBM, covering more than 100 commodities from every country in the world.

The new facilities are open to the public from 8:15 a.m. to 3:45 p.m. daily. Addresses and phone numbers are, for the USBM/USGS Minerals Information Office: Department of the Interior, Mail Stop 2647-MIB, Room 2647, 18th and C Streets, NW, Washington, D.C. 20240, phone (202) 343-5512; and for the USGS Earth Science Information Center: U.S. Geological Survey, Department of the Interior Building, Room 2650, 18th and C Streets, NW, Washington, D.C., 20240, phone (202) 343-8073.

—USGS/USBM news release

USGS names new public affairs officer in Menlo Park

Patricia A. Jorgenson has been named public affairs officer for the U.S. Geological Survey (USGS) in Menlo Park, California, the USGS Western Region headquarters.

She served as deputy chief (1980-1983) and chief (1983-1984) of the USGS Central Region Public Affairs Office in Denver, Colorado, before she resigned to enter private business. She now succeeds Edna G. King, who retired earlier in 1988 after serving in this position for more than eight years.

Jorgenson's special area of responsibility is the eight-state Western Region (Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington). For this region, she will provide special emphasis on earthquakes and other earth hazards.

The USGS Western Region Public Affairs Office can be reached under the following address and telephone number: Public Affairs Office, U.S. Geological Survey, Mail Stop 144, 345 Middlefield Road, Menlo Park, CA 94025, phone (415) 329-4000.

—USGS news release

DOGAMI Governing Board adds new member

Ronald K. Culbertson of Myrtle Creek has been appointed by Governor Neil Goldschmidt and confirmed by the Oregon Senate for a four-year term as member of the Governing Board of the Oregon Department of Geology and Mineral Industries. He succeeds Allen P. Stinchfield of North Bend, whose term ended on June 30.

Ronald K. Culbertson

Culbertson is President of the South Umpqua State Bank in Roseburg. A native of Baker, Oregon, he has worked for more than forty years in the banking business, all of it in Oregon.

Serving with Culbertson on the three-member board are Donald A. Haagensen, currently chairman, a Portland attorney and member of the law firm of Schwabe, Williamson, Wyatt, Moore, and Roberts, and Sidney R. Johnson, president of Johnson Homes in Baker. □

(Netarts Bay, continued from page 106)

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ABSTRACTS

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

CENOZOIC ACTIVE MARGIN AND SHALLOW CASCADES STRUCTURE: COCORP RESULTS FROM WESTERN OREGON, by R. William Keach II (M.S., Cornell University, 1986), 51 p.

COCORP recorded two profiles totaling 98 km in western Oregon in 1984, providing some of the first onshore deep seismic-reflection data from the forearc and arc of an active convergent margin. These data are of lower quality than most COCORP data, but when combined with other geological and geophysical data, they provide some useful insights into the subduction zone beneath Oregon and into extensional structures in the Cascades.

Line 1 crossed the Eocene sediments and underlying pillow basalts of the Coast Range and the western Willamette Valley. Reflections from the Willamette Valley clearly define the lower and western boundary of flat-lying, rhythmically bedded Eocene sediments. These sediments appear to be underlain by up to 8 km of seismically transparent Eocene pillow basalts. Layered reflections at depths of 8-16 km may indicate a remnant crust upon which the Eocene pillow basalts were erupted. East-dipping reflections at depths of 35-40 km may represent the decollement above the subducting Juan de Fuca Plate.

Oregon line 2 crosses the Cenozoic volcanic arc terranes of the Western and High Cascades. Interpretation of COCORP seismic data suggests modification of existing models for normal faulting which postulate a symmetric graben or grabens in the Cascades of Oregon. In the High Cascades along COCORP Oregon line 2, reflections suggest a large, gently west-dipping half-graben with major offset only on the west side of the range. The seismic data, when combined with other geological and geophysical data, suggest that, in general, the High Cascades were built on a series of blocks, rather than a single graben. The blocks were differentially faulted during the Pliocene. Seismic data from the Western Cascades indicate several normal faults with down-to-the-east offset, including a major, previously unidentified fault probably of Miocene age.

RELATIONS BETWEEN GEOLOGY AND MASS-MOVEMENT FEATURES IN A PART OF THE EAST FORK COQUILLE RIVER WATERSHED, SOUTHERN COAST RANGE, OREGON, by Jeffrey W. Lane (M.S., Oregon State University, 1988 [compl. 1987]), 107 p.

Various types of mass-movement features are found in the drainage basin of the East Fork Coquille River in the southern Oregon Coast Range. The distribution and forms of mass-movement features in the area are related to geologic factors and the resultant topography.

The Jurassic Otter Point Formation, a melange of low-grade metamorphic and marine sedimentary rocks, is present in scattered outcrops in the southwest portion of the study area but is not extensive. The Tertiary Roseburg Formation consists primarily of bedded siltstone and is compressed into a series of west- to northwest-striking folds. The overlying Lookingglass, Flournoy, and Tyee Formations consist of rhythmically bedded sandstone and siltstone units with an easterly to northeasterly dip of 5°-15°, decreasing upwards in the stratigraphic section. The units form cuesta ridges with up to 2,000 ft of relief.

The distribution of mass movements is demonstrably related to the bedrock geology and the study area topography. Debris avalanches are more common on the steep slopes underlain by Flournoy Formation and Tyee Formation sandstones, on the obsequent slope of cuesta ridges, and on north-facing slopes.

Soil creep occurs throughout the study area and may be the primary mass-movement form in siltstone terrane, though soil creep was not studied in detail. Slump-earthflows, rockfalls, and rock slumps also occur in the study area though less extensively than debris avalanches.

Stratigraphy and bedrock attitude contributed to the prehistoric occurrence of a major landslide involving Flournoy and Tyee Formation bed rock. The Sitkum landslide dammed the East Fork Coquille River, forming a substantial lake which is now filled with sediments. The form and size of the Sitkum landslide is similar to other landslides which have dammed drainages in the Coast Range, including Look Lake, Triangle Lake, and Drift Creek.

Comparisons with the Loon Lake landslide, which has a known radiocarbon date, provide estimated dates of 3,125 years B.P. for the Sitkum landslide and 10,300 years B.P. for the Triangle Lake landslide.

GEOCHEMICAL FEATURES OF THE BEAR CREEK LAVAS, DESCHUTES AND CROOK COUNTIES, OREGON, by Alan D. Brandon (M.S., University of Oregon, 1987), 122 p.

The Bear Creek lavas and other Neogene basaltic units crop out both along Oregon State Highway 27 between Prineville Reservoir and Millican and along the Bear Creek drainage to the east of Highway 27. Geochemical features of these rocks suggest that two series, Al_2O_3-rich and Al_2O_3-poor series, are similar in major-element contents to high-alumina basalt (HAB) and tholeiitic trends, respectively. Incompatible trace-element enrichments require contamination of the initial melt with a sedimentary component.

Phase equilibria and quantitative trace-element models are most consistent with derivation of the Bear Creek magmas from a depleted peridotite. The evolved Bear Creek magmas (basaltic andesites) are contaminated with a pre-Tertiary graywacke, probably from an accreted terrane that underlies the Bear Creek region and is similar to accreted terranes that crop out in eastern Oregon. The Al_2O_3-rich series underwent assimilation/fractional crystallization to pick up the graywacke signature, while the Al_2O_3-poor series initially acquired this sediment signature and subsequently underwent closed-system fractionation.

GEOLOGY OF THE SULTANA VEIN, BOHEMIA MINING DISTRICT, OREGON, by Stephen M. McChesney (M.A., University of Oregon, 1987), 160 p.

The Sultana Vein, Bohemia mining district, Oregon, is a gold-bearing base-metal sulfide/quartz/adularia vein cutting Tertiary basaltic-andesitic to rhyodacitic tuffs and lavas. Sericitic-argillic alteration parallels the vein, cutting propylitically altered rock.

The vein is in a right-lateral strike-slip fault, striking west-northwest, and dipping vertically. It cuts older northwest- and northeast-trending veins and dilates the northwest-trending veins into ore shoots. A wrench-faulting model suggests right-lateral shear at depth driving the deformation, kinematically consistent with differential extension in the Basin and Range starting 25 m.y. ago.

Base-metal sulfides, arsenic-free pyrite, and gold precipitate early. Paragenetically later tetrahedrite and arsenic-bearing botryoidal pyrite suggest arsenic enrichment of the fluids with time, possibly from a late magmatic source. These late fluids alter early base-metal sulfides to an assemblage of digenite, covellite, and pyrite. Supergene fluids enrich electrum at higher elevations in gold; deeper electrum wires have silver-enriched rims. □

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