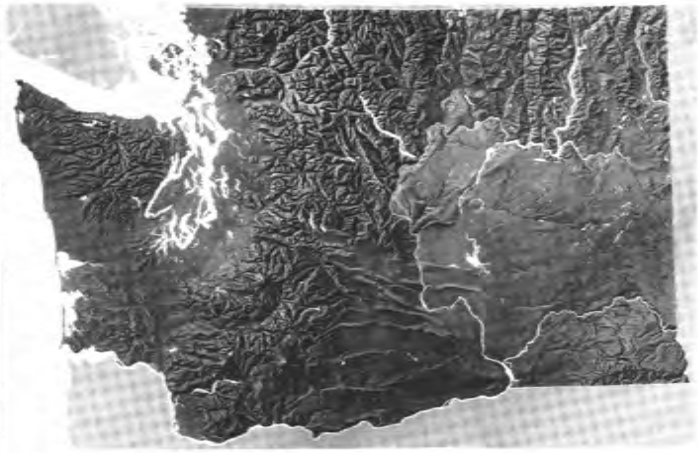

WASHINGTON GEOLOGIC NEWSLETTER

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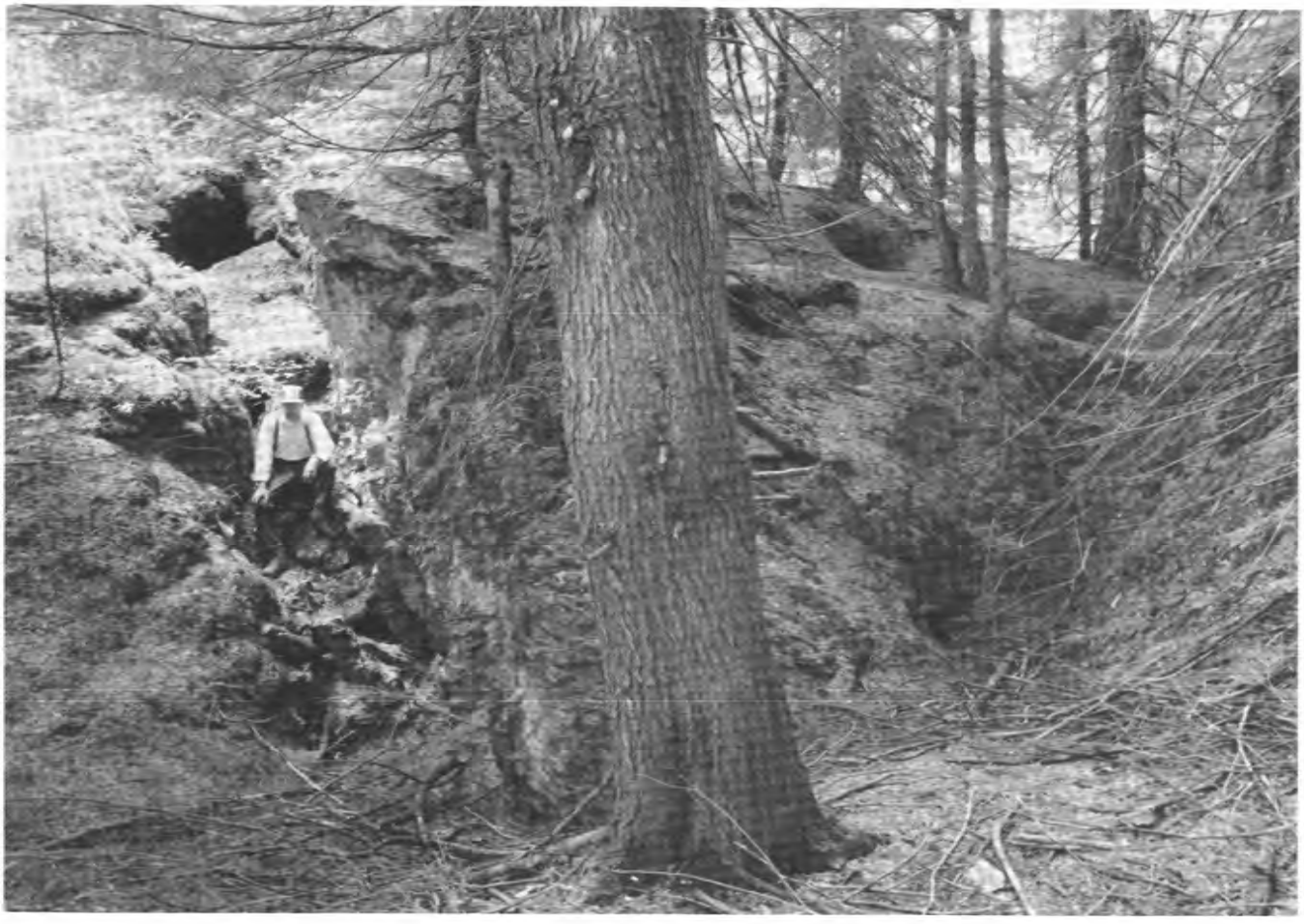
Washington State Department of Natural Resources

Division of Geology and Earth Resources



Jeff Brown provides scale for the width of this tension crack along the crest of Anderson Mountain. The hole behind (above) him is the continuation of this now, largely rubble-filled crack. The chain of holes in the right background appears to mark a parallel crack. (See article, page 3)

READERSHIP SURVEY

— See insert

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WASHINGTON GEOLOGIC NEWSLETTER

The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, geologic maps, and open-file reports. A list of these publications will be sent upon request.

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Oil and Gas Conservation Committee Meeting of October 17, 1989

By Raymond Lasmanis
Oil and Gas Supervisor

The Division of Geology and Earth Resources has statutory responsibility to regulate oil and gas drilling and production, gas storage, geothermal exploration and production, and surface mine reclamation. Our oil and gas regulatory program is one of the most rigorous in the United States. Our staff audits and approves engineering plans and typically makes four 2-day inspections of each well in order to assure compliance with various safety and environmental regulations. The Division's regulatory programs are managed by William Lingley. Lingley and Raymond Lasmanis report to the Washington Oil and Gas Conservation Committee, an independent governing board that oversees all aspects of oil and gas activity in the state.

The Oil and Gas Conservation Committee was created in 1951 in order to prevent waste during production of oil and gas and to provide a safe and healthy environment. The committee is also responsible for protection of correlative rights of oil and gas owners. These rights are used to protect the interests of mineral rights holders who have little knowledge of the oil industry and to resolve disputes between knowledgeable parties.

In 1983, the law (Revised Code of Washington [RCW] 78.52) was amended, establishing the Oil and Gas Conservation Committee to consist of the Land Commissioner, the director of the Department of Ecology, the State Treasurer, and four residents of the State of Washington appointed by the Governor. By statute, three of the public members must reside

(Continued on page 20)

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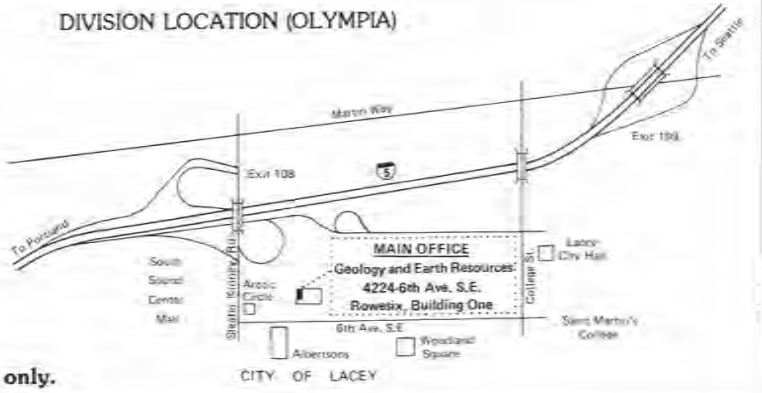

Splitting and Sagging Mountains

By Gerald W. Thorsen

INTRODUCTION

Although not fully understood, mountain splitting (Bergzerreißung) was recognized long before O. Ampferer coined the term in 1939. Ridge-crest cracks and linear depressions along ridge crests (cover and Fig. 1a) had been reported in various mountainous areas of central and eastern Europe; for example, the walls of such depressions in the Alps were called twin ridges (Doppelgrat) by A. Penck (1894). At least one early researcher, apparently at a loss for a better explanation, considered wind erosion as a probable cause (Paschinger, 1928). Now, most geologists agree that features indicative of crestal tension can be the result of sagging (Sackung, a term introduced by Zischinsky, 1966; herein, sackung), or settling and spreading that may involve the slopes of an entire mountain. As Varnes (1978, p. 17) pointed out, "these kinds of movement have come under close study only within the last few decades or so and are being recognized more and more frequently in areas of high relief in many parts of the world." Summaries of early work can be found in Mahr (1977) and Radbruch-Hall (1978).

One does not need to trace the footsteps of those earlier scientists in the Tatra or Carpathian Mountains, or even visit the Alps or the Rockies, to study sackung. The process has been active in postglacial time in the North Cascades, including foothill areas of Skagit County just north of Sedro Woolley. Lyman Hill and Anderson Mountain (locally known as Alger Mountain), flanking the upper Samish River valley (Fig. 2), provide classic examples of landforms that result from the sagging and spreading process. With an elevation of less than 3,400 ft, Anderson Mountain confirms that such slope movements are not confined to the alpine zone.

Sackungen, the slope forms produced by the sackung failure process, warrant distinction from other landslide forms for a variety of reasons. Probably foremost of these is that they can extend over large areas and nevertheless produce only rather subtle features. For example, scarp systems can be so low and discontinuous that individual scarps may not appear to be related. In contrast, a "conventional" landslide of equivalent size will typically have well defined head and flank scarps and a distinctive toe. The difficulty in recognizing sackung features in the area of Anderson Mountain and Lyman Hill is compounded by the generally dense forest cover. Thus, characteristic landforms may be invisible in aerial photos unless the photos were taken soon after timber harvest (Fig. 3); topographic maps have even more limited utility (Fig. 4).

Except for Tabor's (1971) work on ridge-top depressions in the Olympic Mountains and the geomorphic and engineering investigations in the Coast

(a) (b)

Figure 1. Linear pond on the ridge crest of Lyman Hill may indicate spreading, differential erosion by an ice sheet, or both. Views to the south (a) and of the same trough to the north (b).

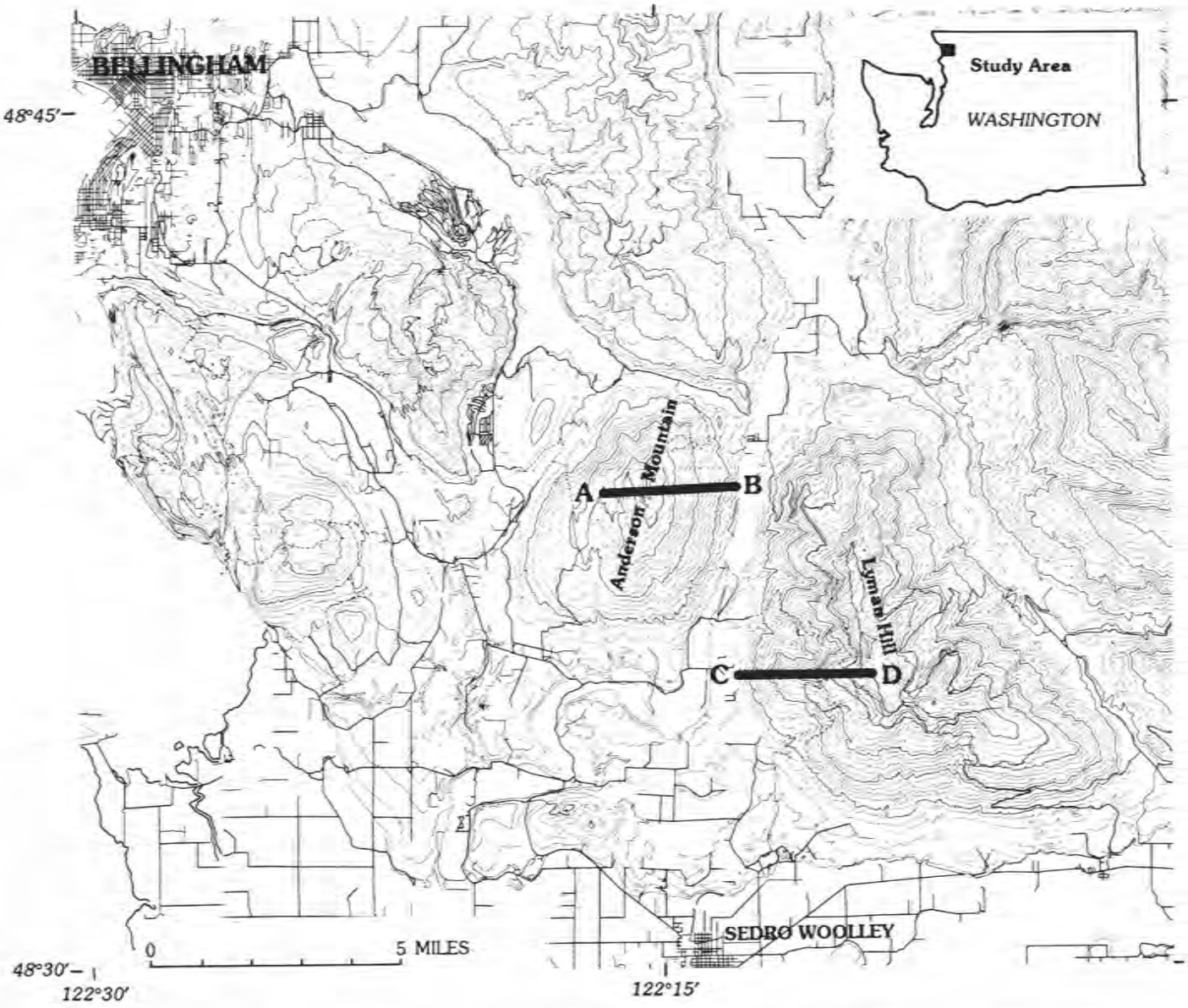

Figure 2. Index map showing the locations of profiles A-B and C-D on Anderson Mountain and Lyman Hill, respectively; this area is in the foothills of the Cascade Range in northwestern Washington. Base from USGS Bellingham 1:100,000 sheet, 1975.

Mountains of British Columbia (for example, Bovis, 1982), studies of these features in the Northwest have largely been confined to the North Cascades of Washington. Most of these investigations, undertaken in the late 1970s and early 1980s, were conducted primarily for the evaluation of seismic hazards to major engineering works, such as dams and nuclear power plants (Dohrenwend and others, 1978; Ertec Northwest, 1981, 1982a, 1982b; Knitter and Fuller, 1982; Beget, 1985). They consisted largely of attempts to establish the epicentral area of the 1872 North Cascades earthquake and to determine the level of activity (or capability) of the Straight Creek fault. One of the major problems facing these investigators was to decipher whether landforms such as uphill-facing scarps were the result of tectonic forces (faulting) or gravity (sackung).

GENERAL DISCUSSION

The particular form of slope failure that characterizes sackung, the settling, sagging, and spreading of a mountain, has been called "depth creep" (Ter-Stepanian, 1966), "large-scale creep" (Tabor, 1971), "gravitational spreading" (Radbruch-Hall and others, 1976), and "bedrock flow" (Varnes, 1978). Generally common to the processes described is the slow

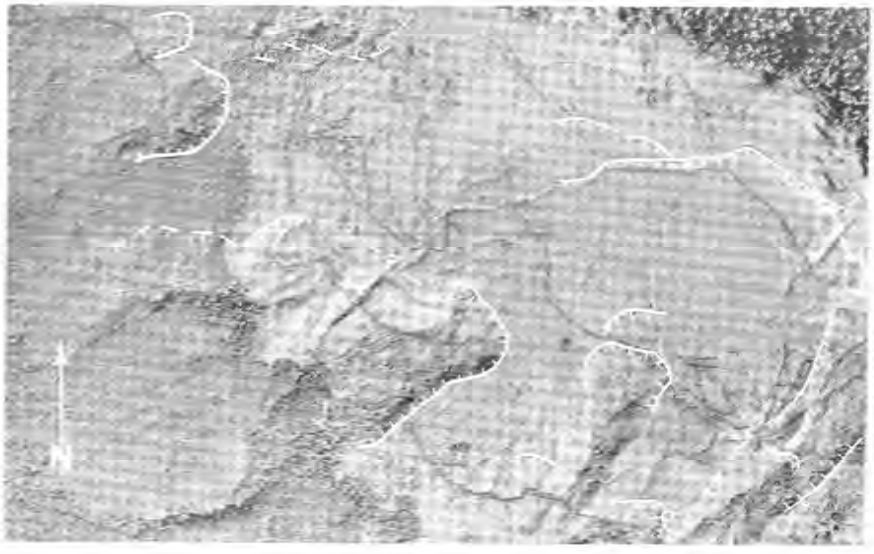

Figure 3. Secondary landslides on the lower, oversteepened flank of Lyman Hill. Note low flank scarps in the upper right and lack of typical landslide topography within the area encompassed by these scarps. (1948 air photo by C. S. Robinson Aerial Surveys, available from U.S. Dept. of Agriculture; 1 in. ≡ 1,900 ft.)

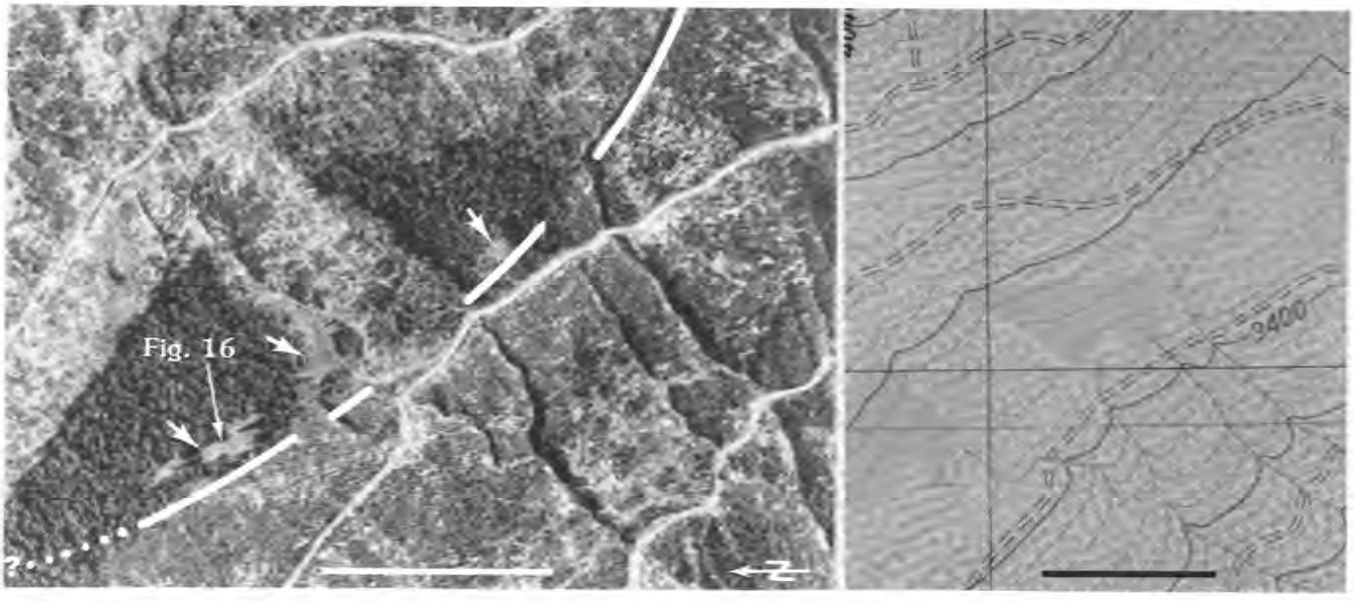

Figure 4. Uphill-facing scarp on a 1983 aerial photograph and on the U.S. Geological Survey Sedro Woolley North quadrangle map (40-ft contours; the bars on the photo and map represent 1,000 ft). The scarp is indicated by a dashed and dotted line. See Figure 16 for a closer view of this scarp. The diversion of generally parallel drainages is the only indication that "something is wrong" on the topopgraphic map. Note the chain of boggy meadows (heavy arrows) in the photograph. (Air photo by Western Aerial Contractors, available from the Washington Dept. of Natural Resources)

movement of extensive areas of slope on myriad poorly defined and discontinuous planes of failure. These zones of failure may extend to depths ranging from tens to hundreds of feet; individual areas involved in movement may encompass square miles of terrain.

As is usual in describing complex slope failures, this form is difficult to pigeonhole. In this discussion I interpret what has happened on Anderson Mountain and Lyman Hill to be in the category that Radbruch-Hall (1978, p. 629) classified as "creep in ... rocks with random discontinuities". (The decision as to whether such creep is "true" landsliding is left to the reader.) In theory, phyllite, the rock making up Anderson Mountain and Lyman Hill, does not have *random* discontinuities: its characteristic sheen would not exist were it not for the parallel orientation of the constituent platy mineral grains, produced during metamorphism. In fact, however, the folding, faulting, and jointing (Fig. 5) that accompanied the emplacement of these rocks at the Earth's surface has rendered them essentially homogeneous and isotropic in strength properties (and ground-water flow)

Figure 5. Step-like knobs on the upper east flank of Lyman Hill, shown at the left center of this photograph, appear to have all moved downslope. Vertical face in the upper right is fractured from top to bottom, suggesting the minimum depth of shattered bedrock.

over extensive areas (Fig. 6). This inherent mechanical weakness is compounded by the fact that the rock is commonly rich in graphite and, in a few places, talc, both good lubricants even when dry. Unfortunately for logging-road builders, slopes here are seldom dry, as testified by ponds on ridges that persist through the dry season (Fig. 1a, 1b).

Given weak materials, ample groundwater, and local relief of 3,000 ft or more, evidence of widespread postglacial slope movement should come as no surprise. Slopes averaging as little as 20° in this area were apparently steep enough to initiate such movement. Whether lower-slope oversteepening (Figs. 7, 8) was a cause or a result of such movement is not clear. The oversteepening could have been caused by accelerated erosion due to the recent continental ice sheet having been much thicker in the valleys than on adjacent ridges. Such erosion could have been enhanced by subglacial meltwater streams, as suggested for areas farther to the south by Booth (1984). Alternately, lower valley-wall oversteepening may have developed due to bulging accompanying the sackung process. Whatever the cause, such oversteepening is quite evident in this area, wherever slopes have not been thoroughly dissected by stream erosion in postglacial time.

DESCRIPTION OF FEATURES

In their analysis of the mechanics of gravitational spreading, Savage and Varnes (1987) were able to explain most of the features that can be seen on

Figure 6. Folded, kinked, and shattered phyllite has little mechanical strength. Faults and joints provide large-scale zones and planes of weakness. Lens cap for scale.

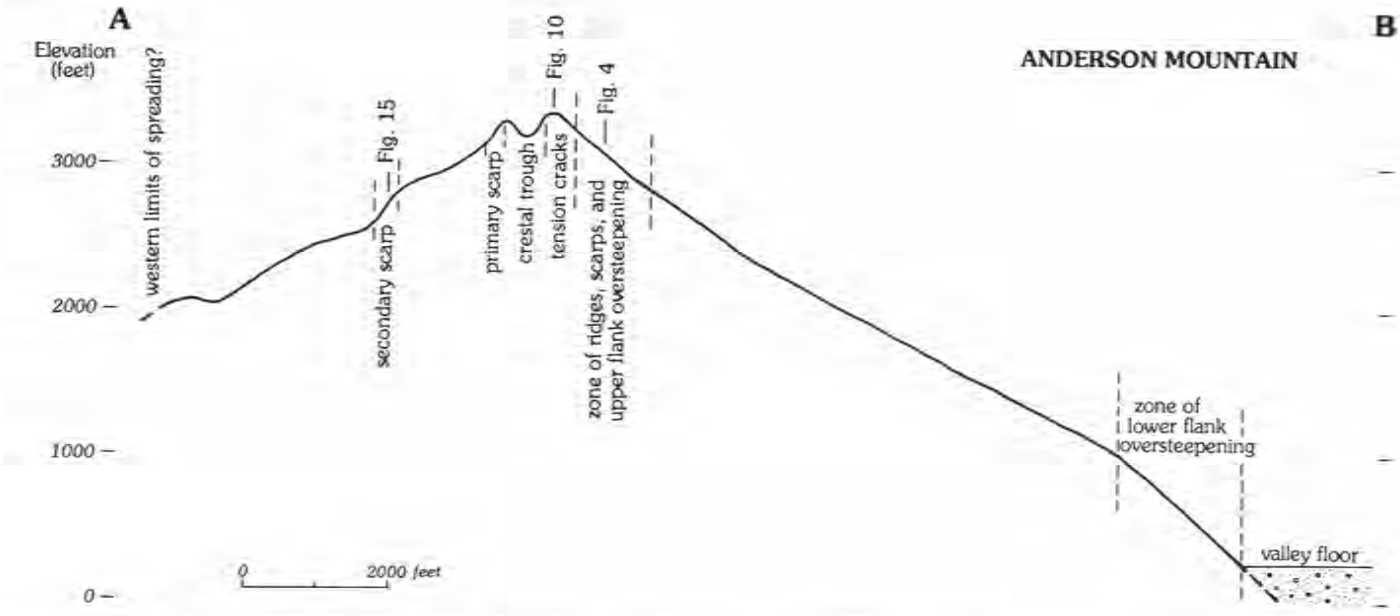

Figure 7. Generalized east-west profile of eastern Anderson (Alger) Mountain. Note the oversteepening of both the upper and lower slopes on the east side. 2x vertical exaggeration to emphasize slope breaks. See also Figure 9.

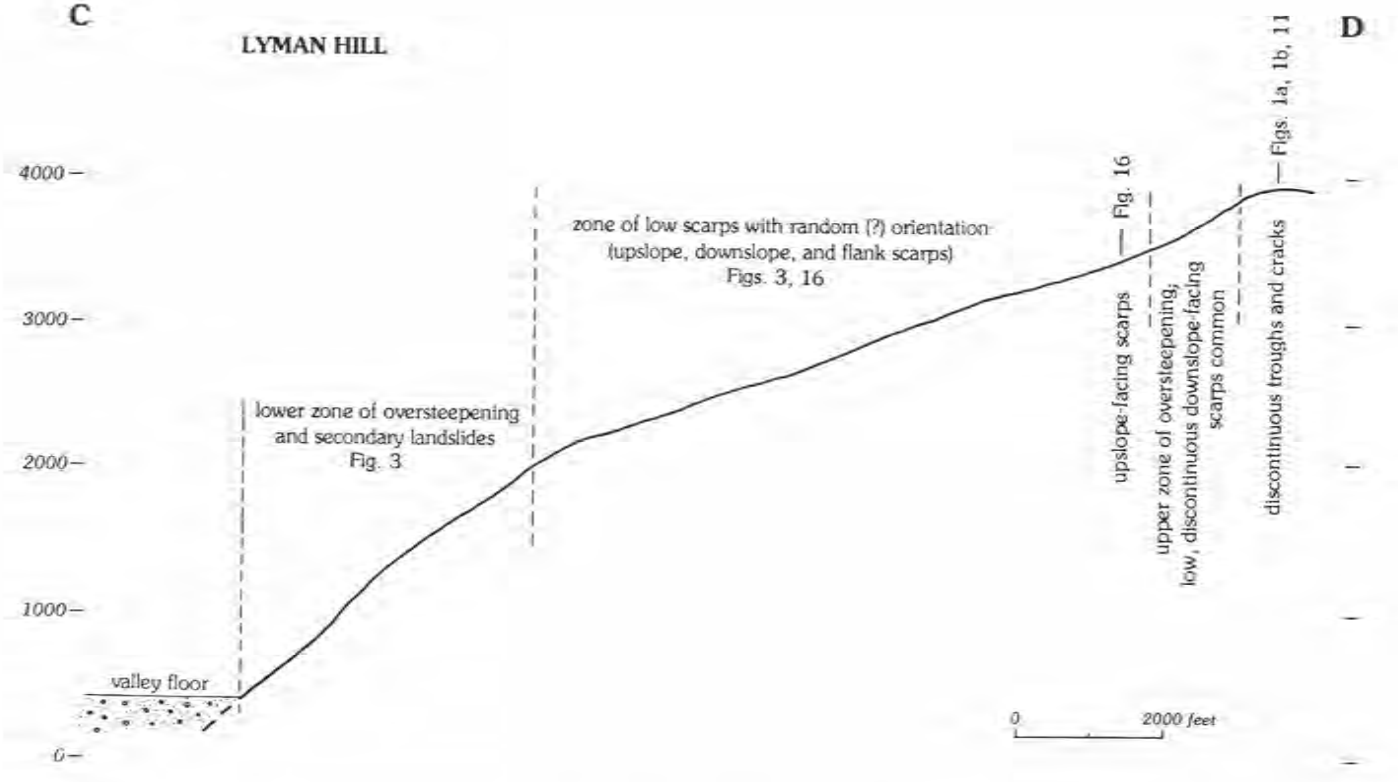

Figure 8. Generalized east-west profile, west flank of Lyman Hill. The location of this profile was selected to avoid areas modified by major streams. 2x vertical exaggeration to emphasize slope breaks. See also Figure 9.

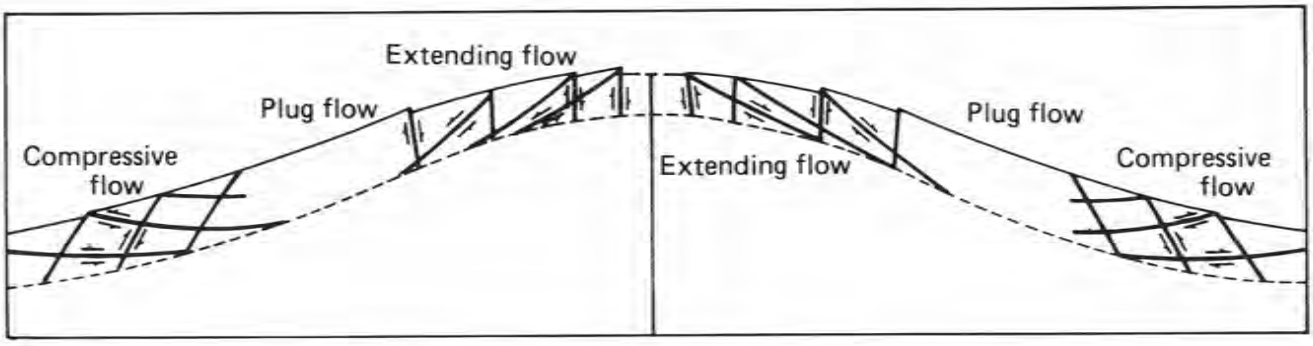

Figure 9. Sketch of flow regions and predicted senses of shear on rupture surfaces for a symmetric gravitating ridge. (Modified from Savage and Varnes, 1981)

Anderson Mountain and Lyman Hill. Their concept, based on "pervasive plastic deformation", identifies regions (from ridge crest to valley) of extending flow, plug flow, and compressive flow (Fig. 9) which appear to correspond to the slope breaks and distribution of landforms in the study area. The slope profiles in Figures 7 and 8, scaled from U.S. Geological Survey topographic maps, show (from crest to valley) oversteepened upper flanks, a midslope area of lower slope angle and relatively planar gross form, and a zone of oversteepened lower slopes.

The crests of both Anderson Mountain and Lyman Hill have many tension cracks parallel to the main ridges (cover and Figs. 10 and 11). Linear troughs (Figs. 1a and 1b) are also common along ridge crests; at least some of these may be graben, as predicted by the model of Savage and Varnes (1987, p. 34). Zones of discontinuous downhill-facing scarps (Fig. 12) are common along the upper flanks of central ridges on both mountains, and these cumulatively account for the upper-flank oversteepening seen on both profiles (Figs. 7 and 8). Anderson Mountain has a small area of knife-edge ridges (Figs. 13 and 14) that also parallel the crest in the region of upper-flank oversteepening. All these features appear to indicate tension, and they lie in Savage and Varnes' area of extending flow (Fig. 9).

Savage and Varnes' model also predicts uphill-facing scarps such as the one shown in Figures 4 and 16. These seem to be uncommon on Lyman Hill and were not found on Anderson Mountain. It should be pointed out, however, that neither ridge has been thoroughly explored. Judging from the example on Lyman Hill, such features would be difficult to detect on aerial photographs where forest cover is dense. The uphill-facing scarps that were found are near the base of the zone of upper-flank oversteepening (Fig. 8) and within the upper part of the band with gentler slope angle. This apparent deviation from the model may not be particularly significant, as much of this elevation band on Lyman Hill has been so dissected by runoff that many late Pleistocene to early Holocene features have probably been erased.

Below the oversteepened upper flanks, a zone of gentler slopes can be seen on eastern Anderson Mountain and western Lyman Hill (Figs. 7, 8). This zone is probably best preserved just south of Thunder Creek basin on Lyman Hill (upper right of Fig. 3), in an area of slope relatively undissected by streams.

Figure 10. Chain of holes in the forest floor indicates the trend of a large tension crack along the crest of Anderson Mountain. Forest soil and vegetation spanning the crack suggest possible historic movement of the underlying bedrock. See also cover photograph and Figure 14, feature c.

Figure 11. Near-vertical crack at the skyline, center, shows considerable continuity. The crack parallels the nearby crest of Lyman Hill. View to the north.

Figure 12. Uppermost scarp along the western crest of Anderson Mountain. (See also Fig. 7; feature d, Fig. 14.)

There, broad expanses of slope are relatively free of scarps. Those that can be seen tend to be low but quite continuous, and they appear to be more or less randomly oriented (facing downhill, uphill, and laterally). (An unusually large mid-slope scarp is present on the less typical western slope of Anderson Mountain (Fig. 15)). The terrain is otherwise essentially intact, with little evidence of typical landslide topography (hummocky ground). What appear to be lateral or flank scarps, generally unpaired, can be seen here and in Thunder Creek basin (west slope of Lyman Hill). It is as though extensive areas had been rafted downslope. Such areas could correspond to the "virtually straight lower slopes where plug flow would dominate with a consequent absence of surface deformation" (Savage and Varnes, 1987, p. 35).

Figure 13. One of several short, knife-edge ridges near and parallel to the crest of Anderson Mountain. Upper Samish River valley and Lyman Hill, top left. Man in the background provides scale. (Feature b, Fig. 14.)

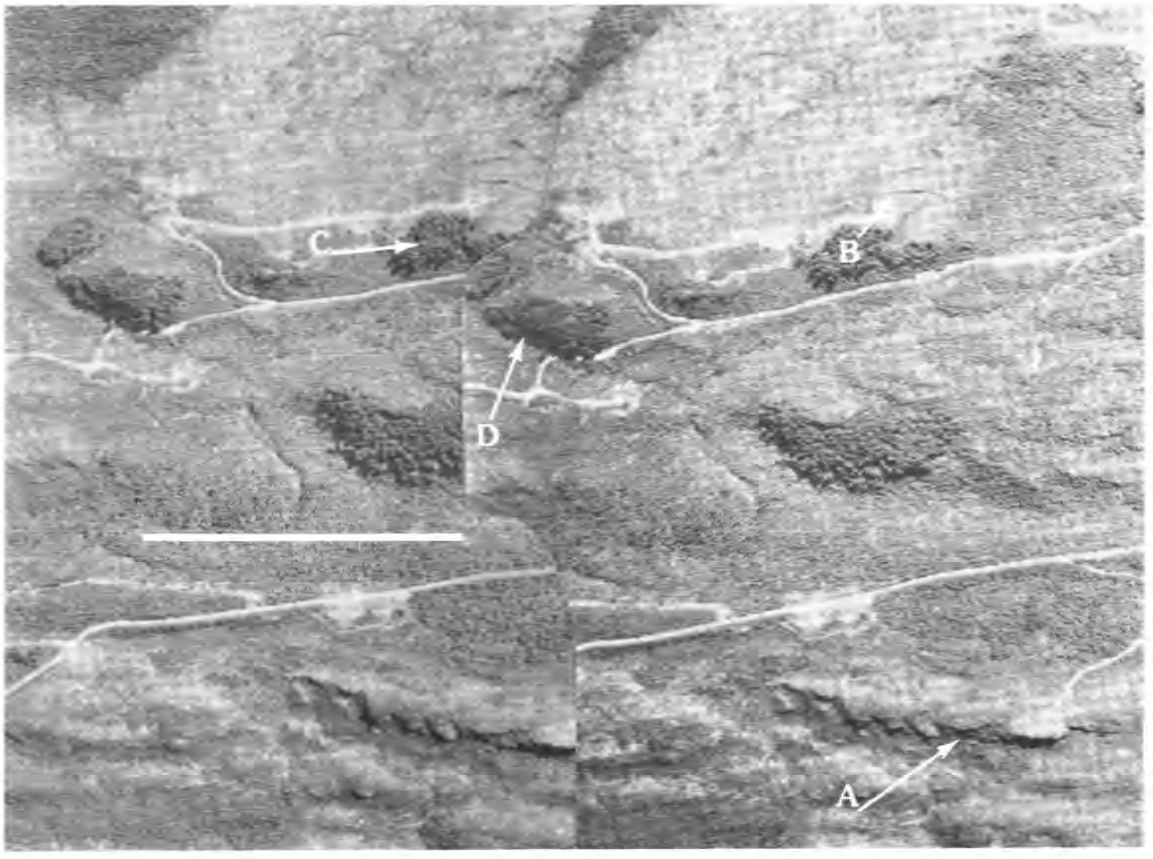

Figure 14. Stereoscopic pair of air photos of Anderson Mountain. Refer to Figures 10, 12, 13, and 15 for details of locations indicated by lettered arrows. Bar represents approximately 1,000 ft. (1987 air photos by Sound Aerial Surveys, available from the Washington Dept. of Natural Resources)

Figure 15. This midslope scarp also parallels the crest of Anderson Mountain. See the profile (Fig. 7) for location in relation to the crestal scarp. (Feature a, Fig. 14.)

Figure 16. An uphill-facing scarp (at the skyline behind the trees) dammed drainages locally, creating this boggy meadow. (See also Fig. 4.) The scarp is estimated to be about 20 ft high.

The lower zone of oversteepening (Fig. 8) on Lyman Hill is an area of numerous conventional landslides (that is, slides with limits generally well defined by distinct headscarps and paired flank scarps, as seen in Fig. 3). If such slides occurred at comparable elevations on Anderson Mountain, they are not apparent today. Continuing a comparison with the Savage and Varnes model, this zone might correspond to their region of compressive flow. This region is theoretically an area of thrusting, but they pointed out that such rupture surfaces are, in general, not seen, and they suggested that the surfaces might be removed by erosion or covered by talus. Either explanation is plausible here, if indeed these surfaces exist. The phyllite is far too weak to preserve such features at the surface.

Determining the age of sackung features on Anderson Mountain and Lyman Hill was beyond the scope of my reconnaissance-level studies, but radiocarbon dates from bogs and ponds formed by uphill-facing scarps (Fig. 16) could provide minimum ages for those landforms. Detailed studies of some similar features to the east, using geomorphic and chronologic methods, yielded varying results. Northwest of Marblemount, sites at Green Lake and Silver Creek showed no offset of the Mazama ash layer, indicating no significant movement in the past 6,900 years. At Helen Buttes, though, an upslope age progression based on tephra and tree-rings (tephrochronology and dendrochronology) was established. The uphill-facing scarp lowest on the hillside shows no movement since before deposition of Mazama ash; scarps

high on the slope apparently formed between 6,900 and 200 yr B.P. (the age of a Mt. Baker tephra that is undisturbed there); and ridge-crest fissures formed between 200 and 65 yr ago (the age of the oldest undisturbed trees at the edge of the large fissure) (Ertec Northwest, 1981, p. 61). At Gamma Ridge near Glacier Peak, Beget (1985) interpreted slope forms and the stratigraphy of tephras (from several volcanoes) deposited behind antislope scarps as indicating three to four episodes of sackung spanning postglacial time, the most recent perhaps tens to hundreds of years ago. The fissures on Anderson Mountain (Fig. 10) could be as young as those on Helen Buttes, but no attempt was made to date the former. None of these investigators could establish a correlation between sackung and seismicity or faulting (Ertec Northwest, 1981, 1982a, 1982b; Knitter and Fuller, 1982; Beget, 1985).

SUMMARY AND CONCLUSIONS

Glacial and meltwater erosion has created thousands of feet of relief in the western foothills of the North Cascades. Where these hills are made up of weak rock, such as pervasively shattered phyllite, slopes apparently sagged and settled as the support of ice filling adjacent valleys was removed. This sagging (sackung) created zones of tension in ridge-crest areas, apparent rafting of extensive areas of bedrock in midslope, and bulging of lower valley walls. These processes left landforms such as crestal tension cracks and scarp-and-ridge systems, random and/or uphill-facing scarps in midslope, and areas of oversteepening and secondary landslides on lower slopes.

Features accompanying the sagging and spreading of mountains made up of weak rock may be extensive but subtle. Some, such as uphill-facing scarps, resemble features that might result from tectonic rather than gravity forces. Because this distinction may have a bearing on seismic-risk assessments, millions of dollars have been spent on studies of these features during geologic investigations relating to the design and safety of dams and nuclear power plants in the region. On a more day-to-day and local level, the recognition of sackung can be of importance to smaller scale activities on foothill slopes, such as residential land development or timber harvest operations. For example, the engineer designing a roadcut below a rock face might calculate the slope stability differently if he or she knew that, instead of bedrock, the face was really a 60-ft boulder supported by mud. Likewise, development at the foot of slopes surrounding Anderson Mountain and Lyman Hill should consider that these weak and wet rocks can engender disastrous debris torrents, as they did on January 10, 1983.

ACKNOWLEDGMENTS

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Nature of the Metaline Formation-Ledbetter Formation Contact and Age of the Metaline Formation in the Clugston Creek Area, Stevens County, Washington: A Reinterpretation

By J. Eric Schuster[1], John E. Repetski[2], Claire Carter[3], J. Thomas Dutro, Jr.[4]

The Kootenay arc is a belt of multiply folded and faulted, low-grade metamorphic, eugeoclinal and miogeoclinal sedimentary rocks that extends from north of Revelstoke, British Columbia, to southwestern Stevens County near the confluence of the Spokane and Columbia Rivers (Mills, 1977, p. 6). Important stratigraphic units in the Washington portion of the Kootenay arc include the Gypsy Quartzite, Maitlen Phyllite, Metaline Limestone, and Ledbetter Slate, all named by Park and Cannon (1943) in the Metaline quadrangle in northern Pend Oreille County. Because all of these formations comprise several lithologic types, recent workers tend to substitute "Formation" for the lithologic parts of the formation names. The Metaline Formation is the host for important zinc-lead deposits in Stevens and Pend Oreille Counties. One of the ore-producing horizons is known as the Josephine breccia, a breccia in carbonate rocks of the Metaline Formation just below the Ledbetter Formation (Mills, 1977, p. 31). Because of its importance as an ore host, the contact zone between the Metaline and Ledbetter Formations has been much studied, and several hypotheses have been advanced to explain its origin. These have been reviewed by Mills (1977, p. 26-30) and include an origin as a normal depositional contact, a fault, and an angular unconformity or disconformity. Mills concluded (1977, p. 28) that the contact is a regional angular unconformity, largely on the basis that the Ledbetter Formation was then thought to rest on different stratigraphic horizons of the Metaline Formation at different places in northeastern Washington where no fault is present. Mills (1977, p. 34-39) also reviewed hypotheses for the origin of the Josephine breccia; he concluded (1977, p. 38) that an origin through solution and collapse best accounted for all characteristics of the breccia.

The Clugston Creek area, located in north-central Stevens County about 10 miles north of Colville, is one location where the Metaline-Ledbetter contact is exposed well enough for careful study. The complex contact, which is folded, involves the middle and upper members of the Metaline Formation and the lower, middle, and upper members of the Ledbetter Formation (Figure 1). Mills' conclusions, noted above, are based in small part on two reports the senior author made on the geology of the Clugston Creek area (Schuster, 1976a, 1976b). In the 1976 reports, Schuster said that the Metaline-Ledbetter contact is a pronounced angular unconformity, that the Ledbetter is an on-lapping formation with its basal beds being younger toward the north, and that the Metaline-Ledbetter contact is depositional, not faulted. The Middle Cambrian age of the lower member of the Metaline Formation, the Ordovician age of the Ledbetter Formation (Park and Cannon, 1943), and the general portrayal in the geologic literature of the Metaline and Ledbetter as geologic units that succeed each other (rather than being even partially coeval) made such an interpretation seem reasonable. Since 1976, new data and criticisms require re-evaluation of the age of the Metaline For-

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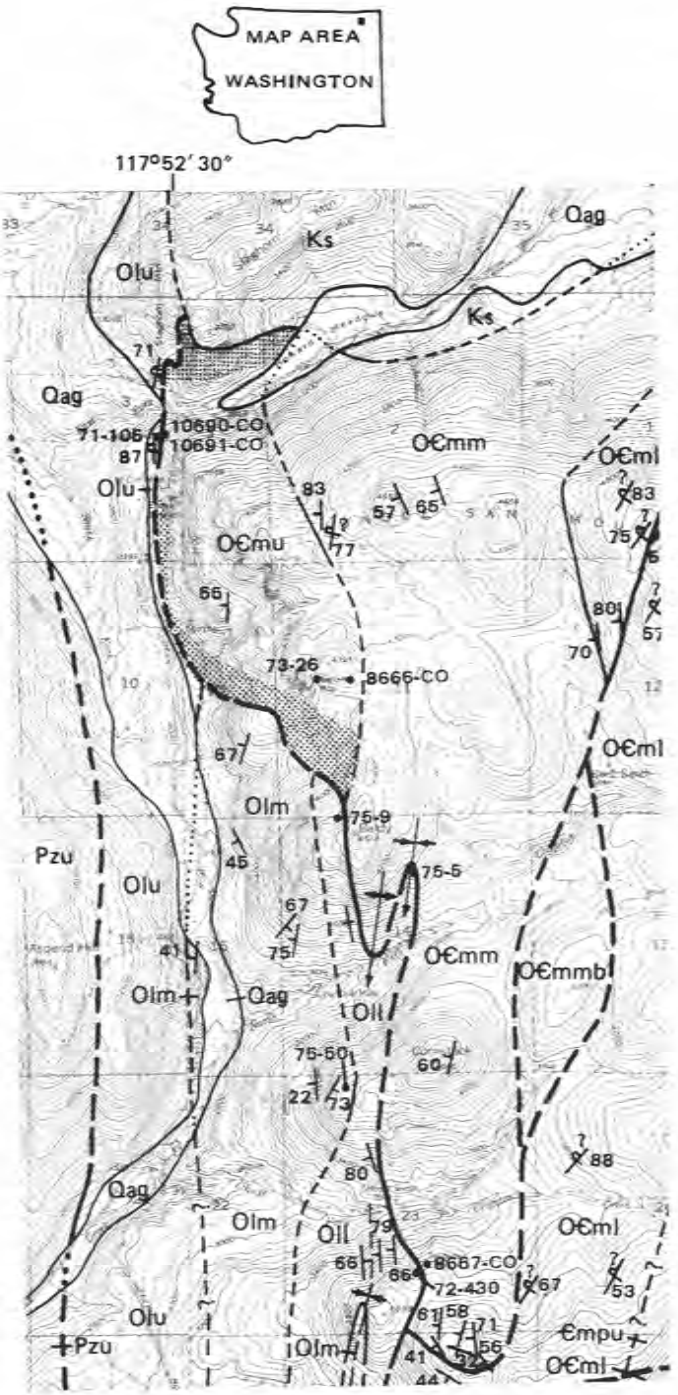

GEOLOGIC MAP UNITS

Qag Quaternary alluvial and glacial deposits

Ks Cretaceous Spirit pluton, granodiorite

Pzu Upper Paleozoic argillite and chert of Laskowski (1982)

Ordovician Ledbetter Formation:

Olu Upper — black slate, carbonate beds in upper part

Olm Middle — slate and argillite with quartzite beds

Oll Lower — slate, argillite, and shale with black limestone and black dolomite beds

Ordovician-Cambrian Metaline Formation:

O€mu Upper — gray, mottled limestone, dolomitized in places (shown by screened area), in places with cherty nodules

O€mm Middle — gray dolomite, in places crystalline, in places well bedded, in places an intraformational breccia (O€mmb)

O€ml Lower — dark gray, thin-bedded limestone with undulatory bedding and brown-weathering shaly interbeds and partings

Cambrian Maitlen Phyllite:

€mpu Upper — phyllite

EXPLANATION

Contact, dashed where approximately located, dotted where concealed

Fault, dashed where approximately located, dotted where concealed

75 Strike and dip of bedding

53 Strike and dip of overturned bedding

72-430 • Fossil locality

Anticlinal axis, showing direction of plunge

Synclinal axis, showing direction of plunge, dashed where approximately located

Modified from Schuster (1976a). Base map from U.S. Geological Survey Gillette Mtn. and Echo Valley 7½ minute quadrangles. Scale 1:48,000.

Figure 1. Geologic map of the Clugston Creek area.

mation and of the contact relation between the Metaline and Ledbetter.

In 1976, Schuster (1976a, p. 11) concluded that evidence for faulting between the Metaline and Ledbetter Formations does not exist in the northern and southern parts of the area shown on Figure 1. For the middle portion, however, in section 14 and the southwest quarter of section 11 (Fig. 1), he reported some evidence for faulting (brecciated Ledbetter and red, iron-oxide-rich soils near the contact). Although the Metaline is commonly disrupted near the contact, the Ledbetter rarely is; graptolites and trilobites are commonly preserved in the Ledbetter up to within one to several feet of the contact. Still, we have not seen the contact in the Clugston Creek area to be a completely undisturbed transition from

carbonate rocks of the Metaline to fine-grained clastic rocks of the Ledbetter. At two localities (71-105/10690-CO/10691-CO and 72-430/8667-CO on Fig. 1), the contact is exposed well enough to reveal small details, and at both places there is a zone a fraction of an inch to several inches thick of unlithified or poorly lithified materials and rock fragments. Perhaps this represents a weathered fault gouge or breccia zone. Most members of field parties the senior author has taken to these two localities since 1976 have found the disruption of the Metaline and (or) the thin disturbed zones between the formations to be permissive evidence of a fault.

Age assignments from four additional fossil localities in the middle dolomite member (locality 8667-CO on Fig. 1) and the upper limestone member (localities 8666-CO, 10690-CO, and 10691-CO on Fig. 1) of the Metaline Formation indicate that the upper part of the formation is younger than previously thought. The age ranges for collections 8666-CO and 8667-CO are rather broad and are based on the known range of the vertebrate genus *Anatolepis*. Collection 10690-CO contains several index species of conodonts that allow assignment of their host strata to the upper part of the Ibexian Series (= upper Canadian Series of earlier usage). Species of both North American Midcontinent (warm, shallow) and North Atlantic (cool, deep) faunal realms are present in the presumed-indigenous assemblage, suggesting a depositional site near or at the continental margin zone of overlap of the two faunal realms. Several reworked species in this sample represent stratigraphic source-levels of both earliest and late early Ibexian age, thereby attesting to the age range of older Metaline strata in this region. Conodont species from the top of the Metaline in the Clugston Creek area (collection 10691-CO) are of Middle Ordovician, Whiterockian, age. The indigenous fauna is entirely of North Atlantic species that correlate most closely with a level in the Llanvirnian Series of British usage. Reworked species in this sample are of the same late Ibexian (= late middle Arenigian) age as the sampled level 100 ft lower (collection 10690-CO).

Previously reported fossils from the Ledbetter (Schuster, 1976a, p. 16) are listed in Table 1, and the fossils from the four more recent localities in the Metaline are listed in Table 2. The age assignments from these collections are listed below and shown on Figure 2.

Ledbetter Formation, localities listed from south to north:

- 72-430 – Early Ordovician
- 75-50 – late Early to early Middle Ordovician
- 75-5 – late Early to early Middle Ordovician
- 75-9 – early Middle Ordovician
- 73-26 – late Middle Ordovician (this locality is not shown as Ledbetter on Fig. 1 because the shale breccia exposure is far too small to show at the scale of the map)
- 71-105 – late Middle Ordovician

Metaline Formation, localities listed from south to north:

- 8667-CO – Late Cambrian to early Middle Ordovician
- 8666-CO – Late Cambrian to early Middle Ordovician
- 10691-CO – Middle Ordovician, most likely latest Arenigian or Llanvirnian (= Whiterockian)
- 10690-CO – At least as young as youngest Early Ordovician (very late Ibexian)

These age interpretations suggest that Metaline deposition extended well into the Ordovician and strongly imply that the Metaline and Ledbetter are partial age equivalents in the Clugston Creek area. Middle Ordovician graptolites from slate in the upper Metaline limestone in the Pend Oreille mine at Metaline Falls (reported in 1961 by R. J. Ross, Jr.[1]) suggest a similar Metaline-Ledbetter relation there. The 1961 report by Ross certainly shows that partial age equivalency between the Metaline and Ledbetter Formations is not a new idea, but perhaps because the report was not widely circulated or the evidence was thought to be explainable by faulting, the idea has not previously gained wide acceptance. Carter (1989) confirms the existence of Middle Ordovician graptolites in slate within the upper part of the Metaline Formation in the Pend Oreille mine.

Partial age equivalency of the Metaline and Ledbetter permits simpler and more likely hypotheses for some geologic relations in the Clugston Creek area:

- First, the Metaline-Ledbetter contact may be either a folded normal depositional contact where limestone and black shale were deposited in an intertonguing relation or a fault that juxtaposed formerly more widely separated facies. A fault origin for the contact in the

[1]Report on referred fossils, shipment PC-61-5D, U.S. Geological Survey Coll. D913-CO, Middle Ordovician graptolites from "Ledbetter slate (?)", 1,700 ft. level of Pend Oreille mine, from a lens in "Mid-Cambrian" Metaline limestone about 40 ft. below the Ledbetter-Metaline contact. Collected by A. E. Weissenborn, U.S. Geological Survey, Spokane. Reported by R. J. Ross, Jr., Nov. 9, 1961. This report is on file at the Division of Geology and Earth Resources.

Table 1. Fossils from the Ledbetter Formation in the Clugston Creek area, Stevens County, Washington. Fossils from localities 71-105, 73-26, 75-9, 75-5, and 75-50 were examined originally by W. B. N. Berry, Department of Paleontology, University of California at Berkeley, and reported in his letters dated September 19, 1975, and November 19, 1975. Fossils from locality 72-430 were examined by M. E. Taylor, U.S. Geological Survey, Denver, and reported in his letter dated March 2, 1976. These letters are on file at the Division of Geology and Earth Resources.

Fossil localities / Fossils	71-105	73-26	75-9	75-5	75-50	72-430
Crustacean:						
Caryocaris sp.						x
Graptolites:						
Climacograptus eximius	x					
Climacograptus spp. (poorly preserved specimens cf. *C. phyllophorus* and *C. modestus*)	x					
Climacograptus spp.		x				
Cryptograptus tricornis	x					
Dicellograptus cf. *D. gurleyi*	x					
Dicellograptus sextans	x					
dichograptid fragments				x	x	
Dicranograptus sp. (cf. *D. nicholsoni* var. ?)	x					
Didymograptus sp. (pendent form – possibly of *D. bifidus* group)				x		
Didymograptus sp. (pendent form of the *D. bifidus – D. protobifidus* type)					x	
Didymograptus sagitticaulis	x					
Diplograptus ?	x					
Glyptograptus sp.	x	x				
Glossograptus cf. *G. acanthus*			x			
Glossograptus hincksii	x					
Hallograptus ?	x					
Isograptus sp. of the *I. victoriae* type--possibly *I. victoriae divergens*			x			
leptograptid or dicellograptid stipe fragments		x				
Orthograptus calcaratus acutus ?	x					
Orthograptus of the *O. truncatus* type ?		x				
Phyllograptus sp.			x	x		
Reteograptus geinitzianus	x					
Tetragraptus cf. *T. serra* ?				x		
Sponge:						
sponge spicules						x
Trilobites:						
Bienvillia sp.						x
Hystricurus aff. *H. genalatus* Ross						x

SAMPLE LOCATIONS: 71-105–Ledbetter Fm. Black slate from cut on Clugston Ck-Onion Ck paved road. Immediately W of contact between Metaline Fm. and Ledbetter Fm. East of center, sec. 3, T37N, R39E.

73-26–Tan shale breccia blocks (Ledbetter Fm.) in upper limestone member of Metaline Formation at Neglected mine. South end of NW¼ sec. 11, T37 N, R39E.

75-9–Ledbetter Fm. Brown shale in old logging roadcut. North end of NW¼ sec. 14, T37N, R39E.

75-5–Ledbetter Fm. Hard brown shale. E1/16 cor., NW¼ sec. 14, T37N, R39E.

75-50–Ledbetter Fm. Black slate. North end of NW¼ sec. 23, T37N, R39E.

72-430–Ledbetter Fm. Thin- to very thin bedded shale within a few feet of the Ledbetter-Metaline contact. Fossils in rubble beside road at Tenderfoot mine. W1/16 corner, SE¼ sec. 23, T37N, R39E.

Table 2. Fossils from the Metaline Formation in the Clugston Creek area, Stevens County, Washington. Samples 8666-CO and 8667-CO were collected by M. E. Taylor, U.S. Geological Survey, Denver, and submitted to J. E. Repetski, U.S. Geological Survey, Reston, for processing. Repetski's report on referred fossils is dated December 2, 1977, and was sent under cover letter dated January 24, 1978. His conclusions are published (Repetski, 1978a, 1978b). Samples 10690-CO and 10691-CO were collected by J. T. Dutro, Jr., U.S. Geological Survey, Washington, D.C., and submitted to Repetski for processing. Repetski's report on referred fossils is dated October 31, 1988. These reports are on file at the Division of Geology and Earth Resources.

Fossils	Fossil localities 8666-CO	8667-CO	10690-CO	10691-CO
Conodonts:				
Probable indigenous fauna:				
Acodus aff. *A. deltatus* Lindström			x	
Bergstroemognathus extensus (Graves & Ellison)			x	
Spinodus spinatus (Hadding)				x
Drepanodus arcuatus Pander			x	
Drepanodus arcuatus Pander ?				x
Drepanodus ? sp.				x
Eucharodus toomeyi (Ethington & Clark)			x	
? *E. toomeyi*			x	
Microzarkodina ? *marathonensis* (Bradshaw)			x	
Oepikodus smithensis Lindström			x	
Oepikodus communis (Ethington & Clark)			x	
Paroistodus parallelus (Pander)			x	
Periodon aculeatus Hadding				x
P. aculeatus and *P. flabellum* [various] skeletal elements				x
Periodon flabellum (Lindström)			x	
Prioniodus sp.				x
Prioniodus ? sp.				x
Protopanderodus rectus (Lindström)			x	
Protopanderodus ? *robustus* (Hadding)				x
Protopanderodus cf. *P. varicostatus* (Sweet & Bergström) sensu Löfgren (1978)				x
aff. *"Scandodus" robustus* Serpagli			x	
Walliserodus australis Serpagli			x	
Walliserodus ethingtoni (Fåhraeus)				x
unassigned drepanodontiform elements			x	x
unassigned oistodontiform elements			x	x
unassigned platform elements				x
unassigned scandodontiform elements			x	
indeterminate elements		x	x	x
possible conodont fragments		x		
Probable reworked taxa:				
Bergstroemognathus extensus (Graves & Ellison)				x
Drepanodus arcuatus Pander				x
Hirsutodontus simplex (Druce & Jones)			x	
Oepikodus communis (Ethington & Clark)				x
O. smithensis Lindström				x
Oneotodus ? sp			x	
Paltodus spurius Ethington & Clark			x	
Paroistodus parallelus (Pander)				x
Periodon flabellum (Lindström)				x
Protoprioniodus aranda Cooper				x
Rossodus sp.			x	
? *Variabiloconus bassleri* (Furnish)			x	

Table 2. Fossils from the Metaline Formation in the Clugston Creek area (continued)

Fossils	Fossil localities	8666-CO	8667-CO	10690-CO	10691-CO
Fish:					
? *Anatolepis* sp		x			
Anatolepis sp.			x		
Other:					
phosphatic brachiopod valves			x		
fragments of phosphatic tubes			x		

SAMPLE LOCATIONS: 8666-CO–Upper Metaline Fm. dolomitic limestone. Between Mt. Baldy and Uncle Sam Mtn., approximately 0.15 km SE of hill 4395, S½NW¼ sec. 11, T37N, R39E.

8667-CO–Upper one foot of middle Metaline Fm. dolomite at this locality, near the south adit of Tenderfoot mine as shown on Gillette Mtn. 7½-min. quadrangle map, W½SE ¼ sec. 23, T37N, R39E. Just across Metaline-Ledbetter contact from locality 72-430.

10690-CO–Upper Metaline Formation limestone about 100 ft below top of the formation at this locality, in roadcut on paved Clugston Creek-Onion Creek road. East of center sec. 3, T37N, R39E.

10691-CO–From the very top of upper Metaline Fm. limestone, to the south along the road from 10690-CO. Just across Metaline-Ledbetter contact from locality 71-105. East of center sec. 3, T37N, R39E.

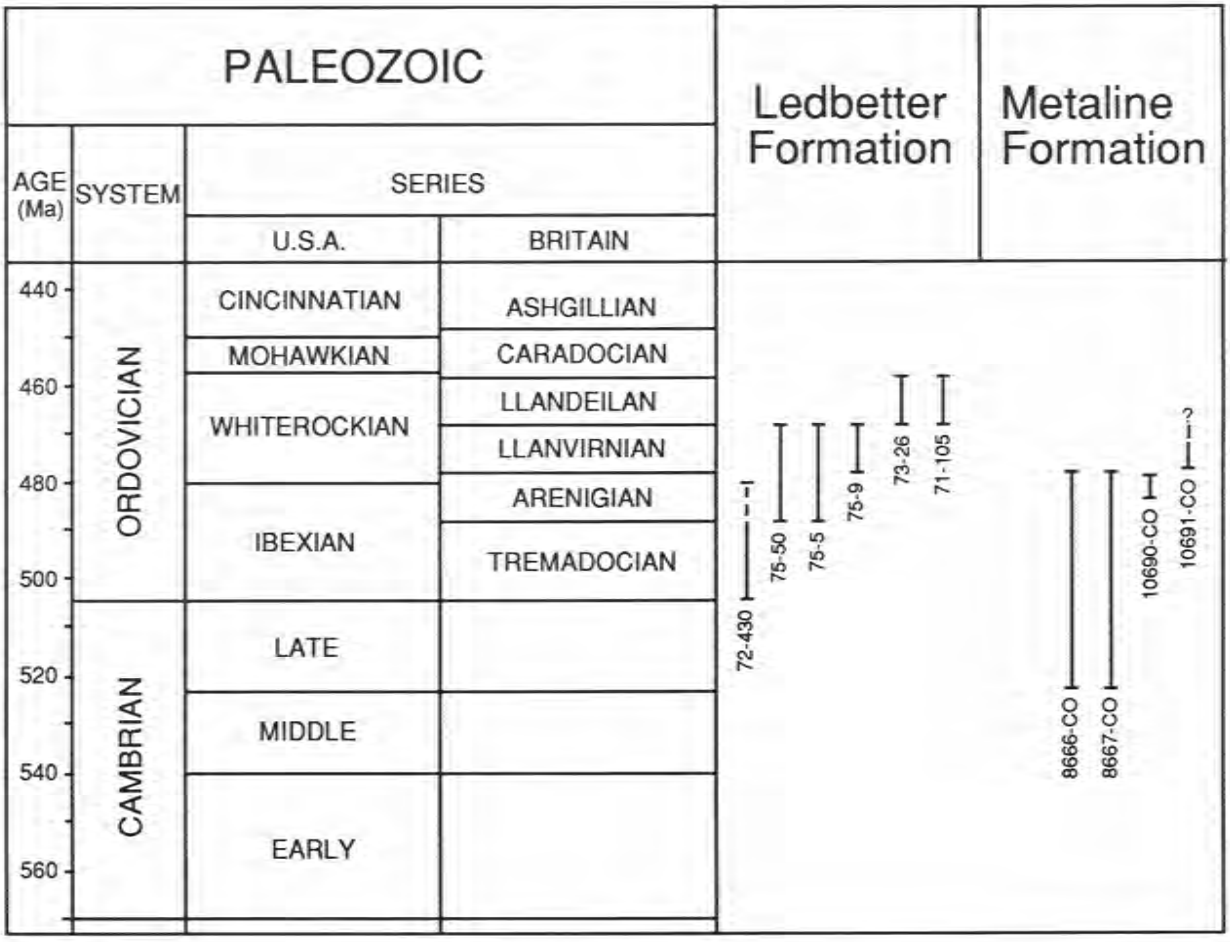

Figure 2. Age assignments for fossil localities in the Clugston Creek area. See Tables 1 and 2 and Fig. 1 for sample locations. Time scale modified from Palmer (1983) and Ross and others (1982).

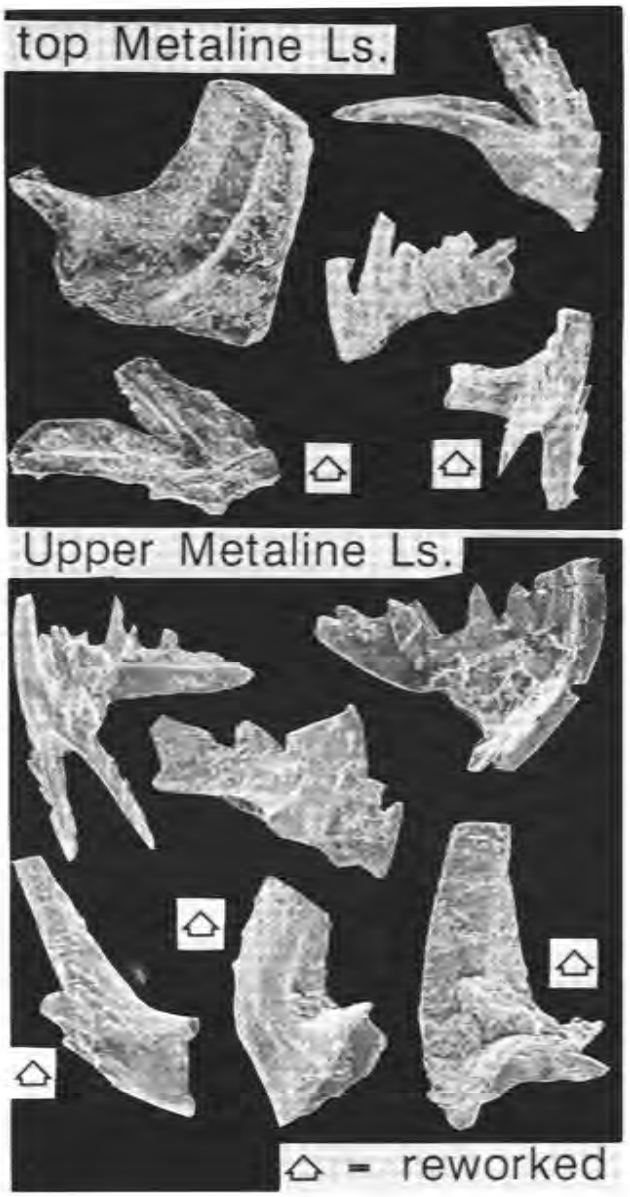

Figure 3. Selected conodont elements from the uppermost part of the Metaline Formation in the Clugston Creek area. Lower photograph shows uppermost Lower Ordovician species and redeposited lower Lower Ordovician species found together in sample 10690-CO from 100 ft below the top of the Metaline. Upper photograph shows Middle Ordovician species and redeposited uppermost Lower Ordovician species from sample 10691-CO from the top foot of Metaline.

Clugston Creek area is the more likely interpretation because (a) the contact has a rather complex shape, some of which is due to folding; (b) the contact truncates members of both the Ledbetter and Metaline Formations; (c) there is a thin zone of unlithified or poorly lithified materials and rock fragments at the contact, perhaps representing a weathered fault gouge or breccia zone; and (d) it is likely that the probably age-equivalent carbonate and black shale facies were originally separated by a much greater distance than they now are.

- Second, the graptolites in the shale breccia fragments at the Neglected mine may have been deposited from an Ordovician sea into a carbonate-depositing (Metaline Formation) environment that was subjected to an occasional influx of clastic sediment (Ledbetter Formation) followed by depositional or diagenetic brecciation. This is a much simpler and more believable interpretation than the earlier one (Schuster, 1976a, p. 22-23) involving uplift, formation of a karst terrane, re-submergence, and deposition of sediment and graptolites in caverns well within the already-lithified upper limestone member of the Metaline Formation.
- Third, because the Ledbetter apparently does not wholly succeed the Metaline but is at least in part a facies of it, there probably is no hiatus between them. This rules out pre-Ledbetter emergence and karstification of the Metaline as a mechanism to form the Josephine breccia. However, the possibility that the breccia formed at some time after the Middle Ordovician must still be evaluated.

ACKNOWLEDGMENTS

This paper was improved greatly by the careful reviews of W. M. Phillips of the Division of Geology and Earth Resources; R. J. Ross, Jr., Colorado School of Mines; and S. C. Finney, California State University at Long Beach.

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Oil and Gas (Continued from page 2)

east of the Cascade Range and one must live west of the Cascades. The committee members are:

Nixon Handy, representing Commissioner Brian Boyle

Walt Lissner, representing Treasurer Daniel Grimm

Bill Miller, representing Department of Ecology Director Christine Gregoire

Don Ford, of Lacey

James Brooks, of Ellensburg*

Hiram White, of Yakima

Simon Martinez, of Moxee City

The committee sets policy, issues orders, and promulgates rules and regulations. In order to accomplish these goals, the committee holds four scheduled meetings each year. The following is a brief description of our last meeting which was held on October 17, in Boullion Hall on the campus of Central Washington University. Agenda items included election of officers, a staff report on oil and gas activity, proposed changes to the Washington Administrative Code (WAC), and a status report on the state's position with respect to the proposed leasing of federal waters for oil and gas exploration.

Ford was elected as chairman, Martinez as chair pro tem, and Handy as executive secretary.

Lingley presented a progress report on oil and gas activity. For the first time in many years, there is no exploration drilling taking place in Washington. Coalbed methane wells drilled by the Carbon River Energy Partnership in Pierce County are in the process of being plugged and abandoned. The Meridian Oil, Inc. 42-14 State well, in Lewis County, was plugged and abandoned at a depth of 8,271 feet. Twin River Oil and Gas, Inc., continues a testing program on their Clallam County Merrill and Ring Co. #25-1 well. In the Bellingham Basin, American Hunter Exploration Ltd. continues to evaluate their American Hunter Birch Bay #1 well.

The administrative rules supporting RCW 78.52 are WAC 344-12. Lingley presented to the committee proposals to change three rules. The rules and issues behind the changes are:

- WAC 344-12-040 (11) - Coalbed methane should be considered gas for the purposes of RCW 78.52 because the correlative rights are normally handled via oil and gas industry contracts and coalbed methane is produced using oilfield technology. However, Lingley recommended that methane gas generated in landfills should not be included under WAC 344-12 because our staff does not have the technical expertise to address complex environmental problems created during degassing of landfills.
- WAC 344-12-070 (1) - Exploratory well data becomes public information after a set period from the date the well is plugged and abandoned. However, some operators have delayed plugging and abandoning dry holes, and consequently the data cannot be released within a reasonable period of time. Lingley proposed that the confidentiality period should commence when the well reaches total depth, with possible extensions for testing operations.
- WAC 344-12-060 (1) - An investigation of drilling costs has shown that the State's bonding thresholds are inadequate for large-diameter, deep exploratory holes, especially when the drilling rig has been removed from the site. Lingley proposed that a graduated bonding scale be established whereby the bond is increased from $25,000 to $150,000 depending on the location of the rig needed to plug the well and the depth of the hole. The basis for this recommendation is that the mobilization and set-up fees for the rig can reach $75,000, and rental rates of $5,000 per day are common.

* Resigned effective Oct. 19, 1989

The committee endorsed the recommendations and instructed staff to prepare draft WAC language for consideration at the next meeting of the Oil and Gas Conservation Committee.

Lasmanis reviewed the State's position with regard to the Department of the Interior's Minerals Management Service (MMS) plans to lease offshore federal waters for oil and gas exploration. The 5-year leasing program is proceeding under the authority of the federal Outer Continental Shelf Lands Act (OCSLA). The Washington State Legislature's Joint Select Committee on Marine and Ocean Resources and Governor Booth Gardner have expressed dissatisfaction with the federal program. On September 1, 1989, Governor Gardner sent a letter to Secretary Manuel Lujan stating that the federal program is skewed and does not represent a proper balance between potential environmental damage and the discovery of oil and gas (as called for in the OCSLA). Further, the governor made four points:

(1) MMS has failed to listen to concerns of Washington residents.

(2) State, local, and tribal governments of the Northwest must be active participants in the OCS decision process.

(3) A critical flaw in the 5-year federal plan is a lack of adequate scientific information, especially environmental data, pertaining to the Northwest.

(4) Areas off the Olympic National Park and our major estuaries must be protected.

A joint declaration by commissioners of coastal Jefferson, Grays Harbor, and Pacific Counties attached to Governor Gardner's letter stated that "the meager amount of oil and gas expected to be found in offshore Washington (Lease Sale 132) does not justify the risks." In their August 30 declaration, a request was made that a 24-mile buffer be established around vulnerable coastal estuaries. In light of the above, the governor has stated that the Interior Department should not include any Northwest OCS areas in the next 5-year leasing plan.

Stephen Palmer, a Division geophysicist, presented a technical talk on the petroleum potential of Washington's Outer Continental Shelf. Palmer concluded that the potential for a single oil discovery from sandstones of the Montesano Formation exceeds the total potential reserves ascribed to the combined Washington/Oregon planning area by MMS and by the U.S. Geological Survey. Palmer substantiated his estimate with data from his comprehensive study of the area's potential. (This study, co-authored by Lingley, is available from the funding organization, Washington Sea Grant Program of the University of Washington in Seattle).

After public comment on the proposed WAC revisions and discussion of the state of the petroleum industry, the meeting was adjourned.

International Archive for Economic Geology

The International Archive for Economic Geology (IAEG) at the American Heritage Center, University of Wyoming, is a research facility and a repository for original manuscripts from the field of economic geology. Recently the records of the Anaconda Company Geological Department covering the years from 1895 to 1985 were presented to IAEG by the ARCO Coal Company.

These records are available for public use at the American Heritage Center. The Anaconda Collection — the largest collection of private mineral/geological data available — is unique in its scope, completeness, and quality. The documents include prospect evaluations, mine examination reports, operating records from Anaconda properties, and studies of broad regional or topical interest.

These records are valuable for scientific, historical and commercial research because they contain data from most of the major mining areas in the United States and the world. The collection has been thoroughly described in a computer inventory that allows efficient access to 1.8 million documents and maps. Printouts of inventory searches for specific inquiries are available.

In addition to the Anaconda Collection, the IAEG has files from more than 170 individual geologists and corporations. For more information on the collections, services offered, and fees for use, contact:

International Archive for Economic Geology
University of Wyoming
Box 3924
Laramie, WY 82701
(307) 766-3704

Staff Notes

Raymond Lasmanis, the Division manager, and **Matt Brunengo**, engineering geologist, both wound up in Europe during late-summer travels.

Latvian-born Lasmanis, who left the Baltic state in 1944, two weeks before the Soviet takeover, returned to Latvia via Estonia. His three-week visit included a one-hour lecture – testing his fluency in Latvian – during a seminar at the Nature Museum in the Latvian capital, Riga. The lecture dealt with the organization and duties of the Department of Natural Resources, specifically the Division of Geology and Earth Resources, according to Lasmanis, and was presented to a group consisting of the chairman of the University of Riga geology department, managers from Latvian Republic geological organizations, professors, geographers, geologists and ecologists.

"It was my first lecture in Latvian," said Lasmanis, who held up for another hour of questions and answers.

The week of Lasmanis' lecture also included an international environmental conference. 'Save the Baltic' was the theme, according to Lasmanis. "It underscores what's going on, the people's awareness of the environment," he said.

During his visit, Lasmanis was able to tour areas of geological interest, in particular a national park. (See accompanying photos, taken by Lasmanis.)

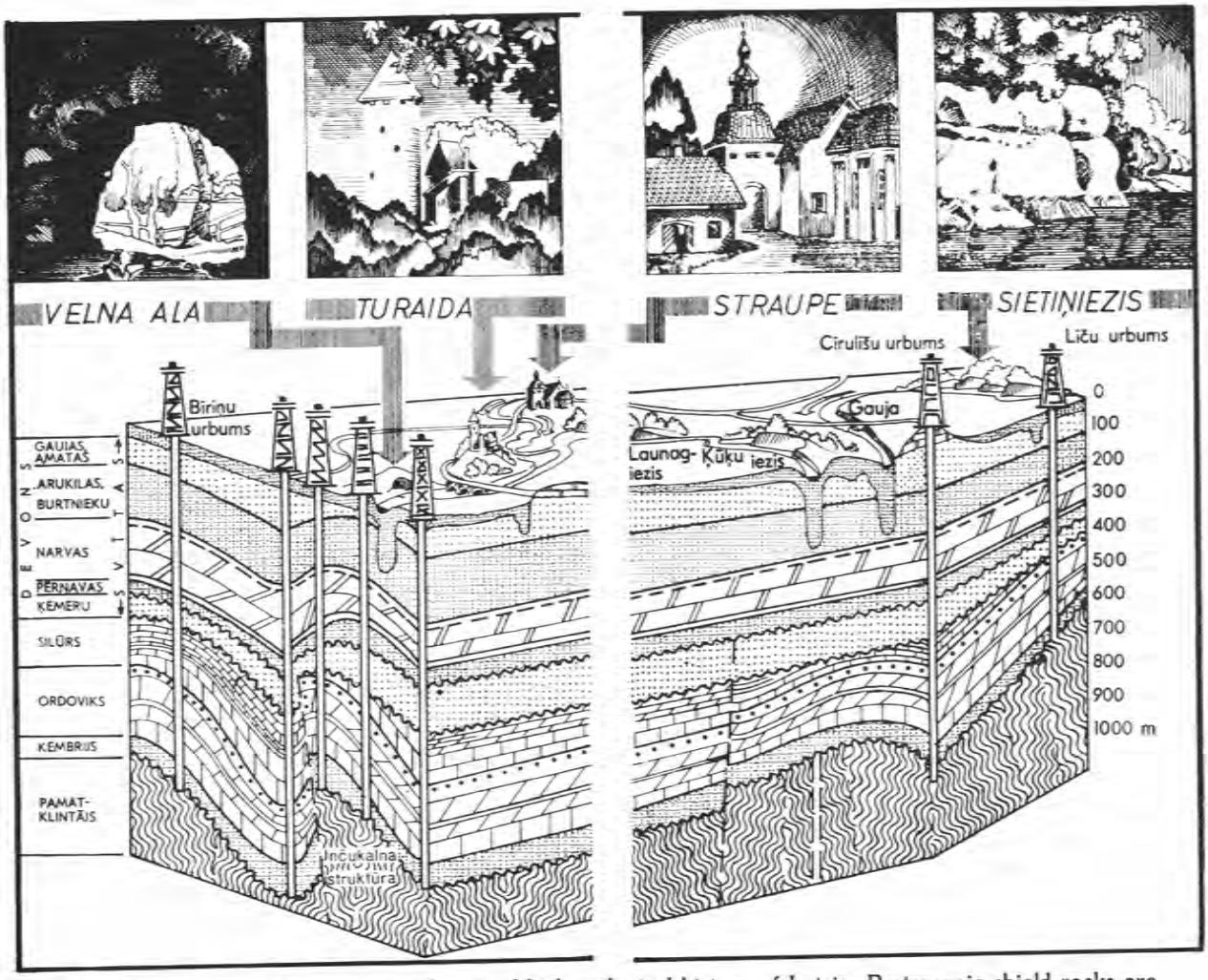
Gutman Cave in Upper Devonian Gauja Sandstone Formation, Gauja National Park, Latvia.

Turaida Castle, Gauja National Park, Latvia.

Also during his visit Lasmanis helped Latvian citizens make a statement. On August 23 he was a link in a human chain that involved 1.7 million persons in a solid line 380 miles long, from Tallinn, the Estonian capital, through Vilnyus, capital of Lithuania, to the Polish border. It was the 50th anniversary of the signing of the Molotov-Ribbentrop non-aggression pact. "Everyone was standing beside the main north-south route from Tallinn to Vilnyus," said Lasmanis. "At 7 p.m. everyone was told to step into the middle of the road. We joined hands and stood there for 15 minutes in a silent protest. The line was four-deep in Riga, where I stood."

Lasmanis' last trip to Latvia was in 1977. "Then there was only one active church," he said. "Now there are 11. And I found the community consisting of scientists and artists, writers and poets to be revitalized. It's a second generation, but the freedom of expression that exists is a tremendous difference."

Initials and dates, Gutman Cave wall, Guaja National Park, Latvia.



The block diagram demonstrates the simplified geological history of Latvia. Proterozoic shield rocks are overlain by a series of sandstones and carbonates of Cambrian, Ordovician, Silurian, and Devonian age. In **Gauja National Park,** colorful Devonian sandstones (equivalent to the Old Red Sandstone of Scotland) form handsome bluffs and serve as a host to numerous caves. The area is also rich with cultural history as seen at the beautifully restored Turaida Castle or ancient towns such as Straupe. (From Kuršs, V.; Eniņš, G.; Stinkule, A.; Straume, J.; Venska, V., 1989, Geoloģiskie objekti Gaujas nacionālajā parkā: Zinātne [Riga, Latvia], p. [17-18]).

Brunengo was among 1,200 delegates to the International Conference on Geomorphology in Frankfurt, held during the second week of his five-week trip. He spent his first week on a field trip, from Hamburg to the Baltic Sea, then south along the eastern fringe of West Germany to the Alps, then down the Rhine River and back to Frankfurt.

The conference week was broken by one-day field trips. Brunengo's group went to a forested mountain area near Frankfurt, looking at erosion problems within the forest.

Jon Harbor and Leal Mertes, University of Washington graduate students, made presentations during the conference. Harbor's talk dealt with numerical modeling of glacial valley development – U-shaped cross-sections and stepped long-profiles. Mertes spoke about measurement of sedimentation on the central Amazon floodplain.

Brunengo spent the rest of his European trip on his own, three days in Bavaria, four more in western Austria, nine in Florence and Rome, and five at Genoa, returning to half of his roots. "I walked around and took pictures of the slide that wiped out my grandmother's former home in 1915," he said. "I told my cousins that made it a work day."

Robert E. (Bob) Derkey joined the Division's Olympia office staff November 1 as a Geologist 2, with a specialty in economic geology. With State Geologist Raymond Lasmanis and Nancy Joseph of the Spokane office, Bob will update the Washington Mineral Inventory. This inventory, last updated in 1956 and published as the Division's Bulletin 37, is recognized as a primary source of Washington mineral data, but is now out of print.

Derkey brings a strong background in economic geology and computer database management to the Division. He received his Ph.D. in geology in 1982 from the University of Idaho, and worked from 1982 to 1988 with the Montana Bureau of Mines and Geology, where, among other things, he created a computerized database listing some of Montana's mineral deposits.

Carl F.T. Harris joined the Olympia office staff November 13 as a Cartographer 2, filling a vacancy that had existed since last January. Harris joins Keith Ikerd and Nancy Eberle in the cartographic unit of the publications staff. Their primary duty for the next several years will be the continued preparation of the Washington State Geologic Map products.

Harris brings experience in both manual and computer-aided cartography. He worked for the U.S. Geological Survey in Vancouver, for Portland General Electric, and most recently in the Intergovernmental Resource Center in Vancouver, Wash. Harris' educational background is in geology and geographic information systems. He is a member of Friends of Mineralogy.

Smithsonian Research Fellowships in Science

The Smithsonian Institution announces its research fellowships for 1990-91 in the field of Earth Sciences. Smithsonian Fellowships are awarded to support independent research in residence at the Smithsonian in association with the research staff and using the Institution's resources.

Predoctoral and postdoctoral fellowship appointments for 6 to 12 months, and graduate student appointments for 10 weeks are awarded. Proposals for research in the following areas may be made:

Meteoritics; mineralogy; paleobiology; petrology; planetary geology; sedimentology; and volcanology.

Applications are due January 15, 1990. For more information and application forms, write: Smithsonian Institution, Office of Fellowships and Grants, 7300 L'Enfant Plaza, Washington, DC 20560. Indicate the particular area in which you propose to conduct research and give the dates of degrees received or expected.

Geologic Guidebook Chapters Available

The Division has a limited number of separate articles from Geologic Guidebook for Washington and Adjacent Areas (Information Circular 86) prepared for last May's Spokane meeting of the Cordilleran Section of the Geological Society of America. Please specify which articles are desired. The separates will be distributed (in reasonable numbers) on a first-come, first-served basis. Please send $1 for postage and handling for each order.

Disaster Training Conference

By Stephen Palmer

The first Disaster Training Conference of the Pacific Rim Disaster Team (PRDT) was held August 23-26, 1989, in Seattle and Tacoma. About 300 people attended the sessions, which included a unique field training exercise at Fort Steilacoom Park southwest of Tacoma. William M. Lokey, director of the Pierce County Department of Emergency Services, obtained permission to have the abandoned Western State Hospital Hill Ward building demolished (Fig. 1) so as to simulate various types of building collapse that might occur during an earthquake. Financing for the controlled demolition was provided by the PRDT.

The PRDT consists of volunteers trained to provide relief services after a natural disaster or life-threatening situation, and is supported solely from private donations. It was formed in January 1989 to fulfill commitments made to the Armenian government following that country's earthquake last December. Members are prepared to assist in search and rescue, radio communications, emergency medicine, and disaster management. These efforts are coordinated with emergency response agencies in the affected area. Additionally, the PRDT is active in domestic and international disaster preparedness and planning, and continues to participate in the Armenian recovery effort.

On the first day of the conference, participants and PRDT members were informally briefed on situations they would encounter in the field during an emergency. Topics included organization and psychology of relief teams during a disaster, types of structural damage and techniques for locating and extricating victims, disaster epidemiology, and management of mass casualties. After the discussions, team participants planned the field exercise.

The second day consisted of presentations on administration and management of disaster situations, medical and pharmaceutical aspects of disaster response, and search and rescue techniques for collapsed buildings. The program included disaster response authorities Fred Krimgold of the Virginia Polytechnic Institute and State University, and Erik Noji of The Johns Hopkins University School of Medicine.

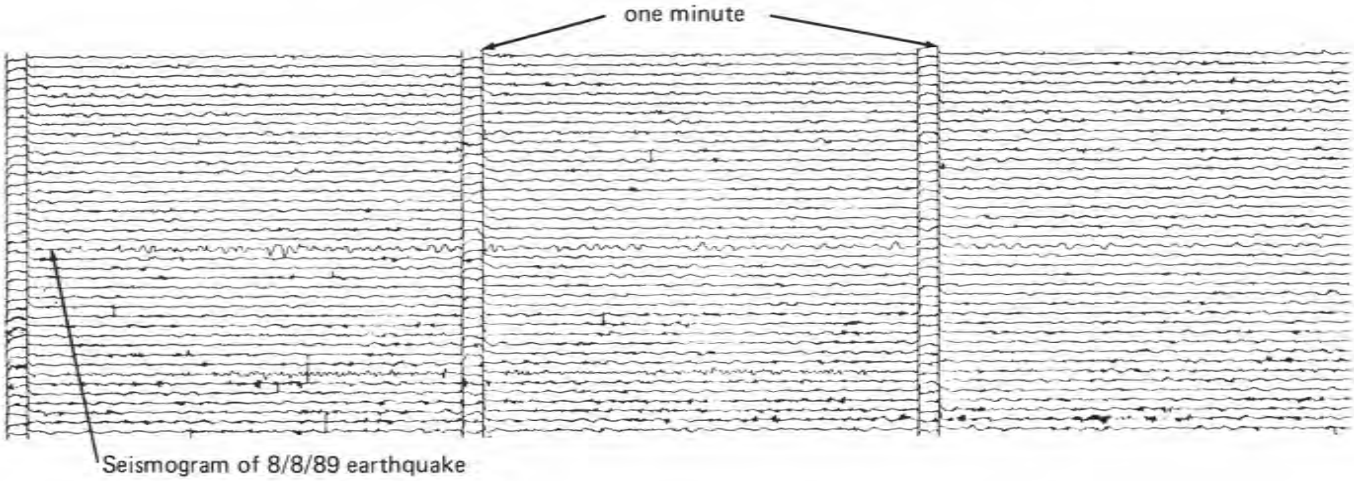
Search and rescue techniques at the demolished Hill Ward building were demonstrated on the third day. Victim location and extrication techniques were applied to the types of structural collapse created by the demolition of the building. Conference attendees had an opportunity to observe and participate in simulated rescue situations in a non-emergency setting.

The last day of the conference focused on a critique of the exercise and on panel discussions of stress response during critical situations, media relations, and legal implications of a disaster. Informal discussions of the lessons learned from past events, as well as new information presented at the meeting, concluded this first Disaster Training Conference.

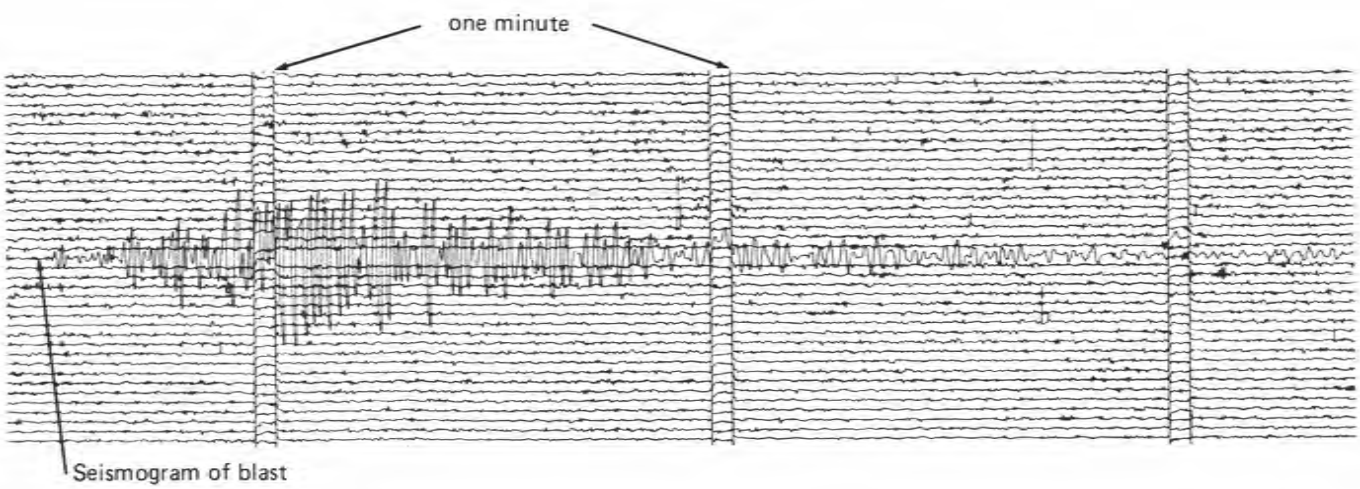
The PRDT intends to hold a training conference yearly. It plans an exercise in Fairbanks, Alaska, in March 1990 to train team members in search and rescue in sub-zero temperatures. The team is chaired by Gary Furlong. Michale Crooks coordinated the recent conference. Contributions are tax deductible. For more information write to: Pacific Rim Disaster Team, 1155 N. 130th St., Suite 420, Seattle, WA 98133, or call (206) 367-7712.

Figure 1. South wing of the Hill Ward building prior to (left) and after (right) its demolition August 19, 1989.

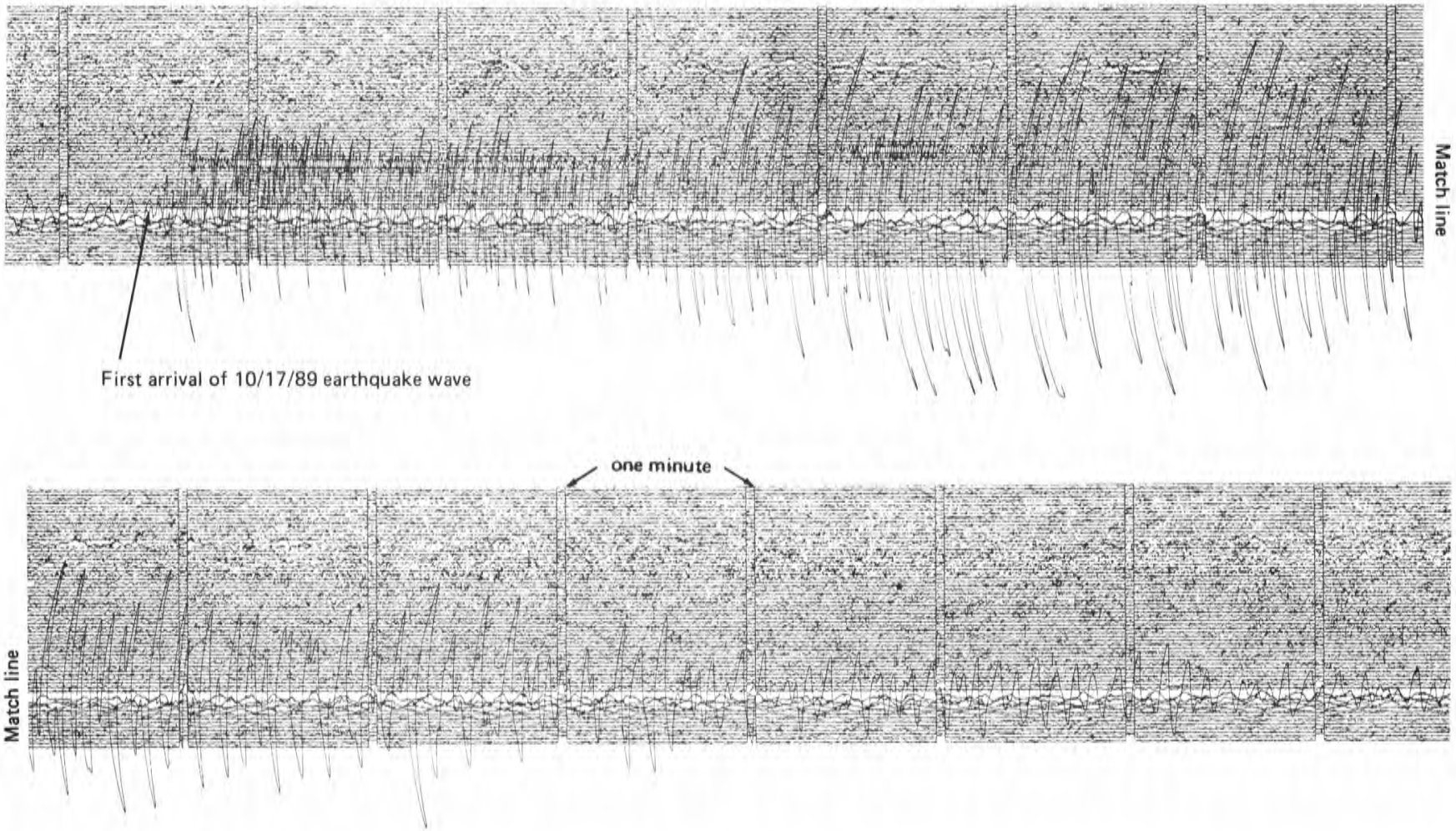
Recent Division Seismograms



Earlier California quake: A magnitude 5.2 earthquake occurred at 1:13 a.m. PDT on August 8, 1989, near Los Gatos and about 13 miles south of San Jose, California, very close to the epicenter of the devastating October 17 earthquake. Comparison of the amplitudes and durations of these two earthquakes as recorded on the Division instrument demonstrates the difference in energy levels of Richter magnitude 5 and 7 earthquakes. The August 8 event, which occurred some 700 miles south of Olympia, was detectable here largely because the earthquake occurred at night, when ambient "noise" levels are low.



Centralia blasts: Relatively small events close to a seismograph, such as the blasts at the coal mine near Centralia (20 miles south of the Division office), produce quite distinct records, whereas at increasing distance from the instrument, some large events, such as the magnitude 5.2 California earthquake, are recorded as smaller amplitude traces.



The Loma Prieta earthquake: This seismogram, recorded on the Division's seismograph, shows the ground motion detected from the October 17, 1989, earthquake that heavily damaged the San Francisco Bay area. The M_S 7.1 earthquake had its epicenter approximately 15 miles south of San Jose on the San Andreas fault. The initial shock in San Francisco lasted about 15 seconds because the various waves had only a few miles to travel from the epicenter. This seismogram shows a sharp onset followed by high-amplitude shaking that lasted approximately 15 minutes due to the attenuation and dispersal of waves over the distance between epicenter and our seismograph. Lower amplitude ground motion is detectable in this record for more than an hour after the initial wave arrival. The earthquake occurred at 5:04 p.m. during the peak of the rush-hour commute, when a great many people were exposed to risk of injury.

Support for Graduate Student Mappers

by

J. Eric Schuster

Since my last report of progress (Schuster, 1988), the Division has again advertised for geologic mapping and mapping-related proposals from members of the academic community. The intent of the graduate student support program is to help generate geologic maps and mapping-related data for use in updating the state geologic map, to encourage graduate students to do geologic mapping as part of their programs for advanced degrees, and to build and maintain closer working relationships between the Division and the geology departments of our institutions of higher education.

Interest in our support program is apparently on the increase — this year, for the first time in its six-year history, we received more proposals than we were able to fund. Those proposals funded for fiscal year 1990 (July 1, 1989, through June 30, 1990) number 11 and total $12,686. One proposal for fiscal year 1991 was funded for $1,600. All funded proposals are listed in Table 1.

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Schuster, J. E., 1988, State geologic map progress: Washington Geologic Newsletter, v. 16, no. 4, p. 20-23.

Bernard Dougan, a graduate student at Western Washington University, examines an outcrop of the Cascade River schist near Cache Col in the North Cascades of Washington. In this area, the Cascade River schist consists of a metatuff conglomerate with highly strained white volcanic cobbles. Dougan is studying the history and character of rock deformation, particularly faulting, in this portion of the North Cascades. (Photograph by W. M. Phillips).

Division geologists Hank Schasse (left) and Josh Logan (center) inspect a thrust fault in the Crescent Formation with Sonja Bickel, Univ. of Puget Sound. Bickel is studying the geochemistry and stratigraphy of this formation in the Tunnel Creek area near Brinnon, WA. Schasse's hands are on the slickensided fault plane. S. Babcock and D. C. Engebretson, Western Washington Univ., and K. P. Clark, Univ. of Puget Sound, have evidence that the Crescent has an apparent exposure thickness of 20 km, which would make it one of the world's thickest basalt accumulations. (Photograph by W. M. Phillips).

Table 1. Proposals funded under graduate student support program (f, faculty)

Name	Fiscal Year	University	Project Title
Sonja Bickel	1990	University of Puget Sound	Geochemical and stratigraphic analysis of the Crescent Formation of the southern Olympic Mountains
Mark T. Brandon (f)	1990	Yale University	Geochemical analysis of basalt blocks within the core of the Olympic Mountains
Arthur R. Campbell	1990	University of Washington	Geology of the Lost Peak-Monument Peak area, North Cascades, Washington
Ralph L. Dawes	1990	University of Washington	Petrogenetic aspects of Late Cretaceous plutons, northern Entiat Mountains, Washington State
Christopher G. DiLeonardo (f)	1990	De Anza College (CA)	Structure and stratigraphy of the North Creek volcanics, northeastern Cascades, Washington
Bernard Dougan	1990	Western Washington University	Geology of the Magic Mountain and LeConte faults, North Cascades, Washington
David C. Engebretson (f), R. Scott Babcock (f) and Kenneth P. Clark (f)	1990	Western Washington University, Western Washington University, University of Puget Sound	A detailed study of two transects within the thickest portions of the Crescent Formation on the eastern Olympic Peninsula, Washington
James E. Evans (f)	1991	Bowling Green State University (OH)	Sedimentology and stratigraphic relationships of Tertiary sedimentary units within the Sauk River 1:100,000 quadrangle
Gary K. Hurban	1990	Western Washington University	Structure, geochronology, and petrology of the Holden Lake area, North Cascades, Washington
Moira Smith	1990	University of Arizona	Structural and stratigraphic investigation of the Covada Group, SE 1/4 Rice and SW 1/4 Kentry Ridge 7.5 minute quadrangles, Washington
James D. Suydam	1990	Washington State University	Sedimentology and stratigraphy of the Eocene Klondike Mountain Formation in northern Okanogan, Ferry, and Stevens Counties, Washington
Laureen Wagoner	1990	Washington State University	Geochemistry and correlation of glassy flows, upper Klondike Mountain Formation, Curlew quadrangle, Ferry County, Washington

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Washington Division of Geology and Earth Resources Library

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Northeast Washington Projects Completed

Two research projects, both in northeastern Washington, have been completed under grants from the Washington State Mining and Mineral Research Institute. Following are summaries of the projects:

Evolution of ore fluids, Overlook gold deposit, Republic Mining District

Principal investigator: Bruce Nelson (University of Washington Dept. of Geological Sciences)

The grant supported petrographic, compositional, and fluid inclusion studies of diamond drill core samples of the Overlook magnetite-hosted gold deposit, obtained from Echo Bay Exploration, Inc. This work represents the initial stage of research to determine the origin, chemistry, and interaction with host-rocks of ore-bearing fluids at the Overlook site. The research, constituting the doctoral dissertation project of Michael Rasmussen, a University of Washington graduate student in economic geology, is significant for several reasons:

- The Overlook deposit is projected to be one of the largest gold producers in the Pacific Northwest (approximately 100,000 oz Au/year).
- The Overlook deposit represents a type of deposit that is without close analogue in the geological literature. Geochemical characterization of this deposit may aid in the discovery of similar ones in the Northwest.
- Study of the geologic setting of the Overlook permits a natural test of recent developments in the theory and experimental geochemistry of gold deposits.

Work to date has emphasized determination of the ore-mineral paragenetic sequence and the physical conditions of mineralization. Mineral paragenesis has been worked out for the stockwork portion of the ore system, but is incomplete for the replacement zones. Twelve electron microprobe analyses indicate the pressure at crystallization of these minerals to be 0.67 ± 0.35 kbars (depth of 2.0 ± 1 km).

Fluid inclusion analysis of presumed primary inclusions in gangue quartz crystals from stockwork veins has yielded homogenization temperatures of 300°-390°C and melting temperatures averaging -2.0°C. The temperatures at which these quartz crystals are inferred to have crystallized range from 350°-450°C. With the reliability of electron microscope in question, stable isotope geothermometry research is in progress to confirm or invalidate the technique in this mineral system.

Distribution and behavior of cesium in rocks associated with gold, silver, molybdenum, and uranium deposits from northeastern Washington

Project chief: Mohammed Ikramuddin (Eastern Washington University Dept. of Geology)

A rapid and precise method has been developed for the determination of Cs in geological materials by Zeeman graphite furnace atomic absorption spectrometry. Using this method, about 300 rocks associated with gold, silver, molybdenum, and uranium from the western United States were analyzed. In all the mineralized areas, hydrothermally altered rocks are Cs-enriched by a factor of 2 to 100 or more; even some quartz and quartz-carbonate veins show high Cs contents. The highly mineralized rocks and veins have extremely low K/Cs ratios. Ternary relations among K, Rb, and Cs separate mineralized and unmineralized rocks into distinct populations regardless of rock types, highly mineralized rocks and veins falling near the Cs apex. The results obtained in this study suggest that Cs and the K/Cs ratio may be useful guides in delineating hydrothermal mineral deposits formed at various temperatures. Cesium can form broader dispersion halos and may prove to be a better pathfinder element than thallium in reconnaissance types of surveys.

Ores of Okanogan

Ex-Governor Laughton's Observations of the Mines

Their Magnitude Attracting Very General Attention

The Boundaries of the Mining Region and the Character of the Mineral Found Therein Described

EDITOR'S NOTE: This story first appeared in the *Spokane Morning Review*, in its February 24, 1889 issue.

Ex-Governor C. E. Laughton, formerly of Nevada, but now a resident of Washington, writes to the editor of the Carson, Nevada, Appeal:

"Answering your inquiry for general information respecting mining interests and developments in Okanogan county, in the territory, which, by their magnitude, are attracting so much attention, I know you will kindly allow me, in order to clearly reply, to briefly review the facts connected with their discovery, location and subsequent development.

"Okanogan county comprises all that part of Stevens county west of the Columbia guide meridian. It does not appear on any map of Washington, as it was only created by an act of legislature passed at its session of 1887-88. For many years mythical stories of deposits of rich galena silver, found in that section, were current; but it then formed a part of the Moses Indian reservation, and neither prospectors nor white men were allowed within its precincts. In 1886, however, this reservation was vacated by executive order, and during that autumn some hundred or more mineral claims were located on the Conconully (then called Salmon) river. In 1887 further locations and new discover[ies] were made, and last year there were opened within a radius of thirty miles from Conconully five other new mining districts. The country in which minerals are found embraces a strip thirty miles wide and probably at least a hundred miles long.

"The Salmon river mining district was the first mining district organized in the county, and the various mining locations (upwards of a thousand in number) made in this district, surround the town of Conconully, which is now the county seat of Okanogan county. There are three routes from the Northern Pacific railway by which these mines and town may be reached; the better route for winter travel is from Spokane Falls to Davenport by rail, and thence about 100 miles by stage, the trip consuming about two days and nights; there is also a stage route from Sprague, but as it is little traveled it is not a popular route. In the spring, summer and fall, a very pleasant means of travel is from Ellensburgh [sic] by stage to the Columbia River, thence by steamer to the mouth of the Okanogan river, and thence by stage to Conconnully [sic].

"In all the developments made thus far, the ore is a galena silver, showing gray copper, brittle silver, bismuth silver, and occasionally seams and pockets of chloride. This rock carries from 40 to 50 per cent lead; traces of gold with a little iron and zinc; Professor Price, the eminent metallurgist of San Francisco, pronounces it the [richest?] smelting ore which he

has ever handled. The grade of the ore in silver varies somewhat, but it may safely be called a high grade proposition, as assays taken generally from the various ledges which have thus far been developed will, I believe, show an average value of at least forty ounces to the ton. The veins have a general direction of northeast and southwest, dipping from twenty to forty degrees, east, and are composed of live quartz and quartzite, with well defined walls of clay or talc in porphyry, porphyritic granite, and granite country rock. The pay streak in the ore chute varies from eighteen inches to four feet in width.

"The Salmon River Mill and Mining company has erected a concentrating plant in this district with a capacity of seventy-five tons per day. These works are situated on the Conconully river, about three-quarters of a mile above the town of the same name, and, being of easy access to all the mines in the Salmon river district, will form a valuable adjunct to the treatment of the ores.

"A lack of railroad communication and transportation is the only impediment to the immediate development of this entire country, and the Northern Pacific railroad as well as the Seattle, Lake Shore & Eastern, have each begun lines respectively from Cheney and Spokane Falls northward; both lines are now completed and running forty miles to Davenport, and I am assured by executive officers of these roads that each will have a line to the Okanogan river before the close of the present year; this will bring them to within about twenty miles of this group of mines, and Conconully. While the fact militates seriously against the immediate output of our mines, it at the same time renders mining values much less than they would assuredly be, had we now the advantage of direct railroad transportation. As a consequence, intending investors will never be able to obtain mining property at as low figure in this and contiguous camps as now. This is a fact worthy of, and to which I desire to call attention. It has been the policy of those of us who have interests there to keep down speculative, prospective and locators' values; and as a consequence, values are now upon a conservative basis.

"The country is most delightfully wooded and watered; in nearly every case the claims can be worked by tunneling, and it is the most favorably situated for mining, as respects its natural resources, of any mining camp I have ever seen.

"Our ores can be treated and marketed at Helena, Montana, or at Tacoma where Dennis Ryan is now erecting a 200 ton smelter, or they can be shipped East to Salt Lake, Denver, St. Louis or Omaha. It is a mining country with a great future, and when capital shall have been expended in its intelligent development, the output will astonish the mining world; and unless all indications are at fault, will rival our Old Comstock in its palmy days."

Division to Build Library of Coastal Subsurface Geology and Geophysics

The Division of Geology and Earth Resources is building a library of subsurface geology and geophysics for coastal Washington. The library will contain mainly reproducible copies of reflection and refraction seismic data together with histories, ditch cuttings, and core samples from offshore and Puget Basin wells. The library and a publication describing its contents are being supported by a grant from the Minerals Management Service through Cooperative Agreement No. 14-12-0001-30432.

While numerous geophysical and geological data sets have been acquired in the area of coastal Washington, most of these data are difficult to obtain. Sepia prints and analog tapes that comprise the originals of some sets are beginning to decay. Some petroleum industry data, acquired in areas not favorable for hydrocarbon accumulation, could be made available to the public through this library.

By constructing the library, the Division hopes to provide a source of data for use in research, industry, and education. Most of these data will be readily available to the public for the cost of reproduction. Sample sets will continue to be available at our offices for non-destructive analysis. Our core storage facilities will be upgraded to facilitate use of these samples. Well histories and miscellaneous information such as historical news clippings will be available for inspection or reproduction on microfiche.

The Division will welcome data or other contributions to this project. For further information, please contact William Lingley or Linden Rhoads at (206) 459-6372.

The Better to Communicate

The Division has added a facsimile machine to its communications system. The number is:
(206) 459-6380.

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