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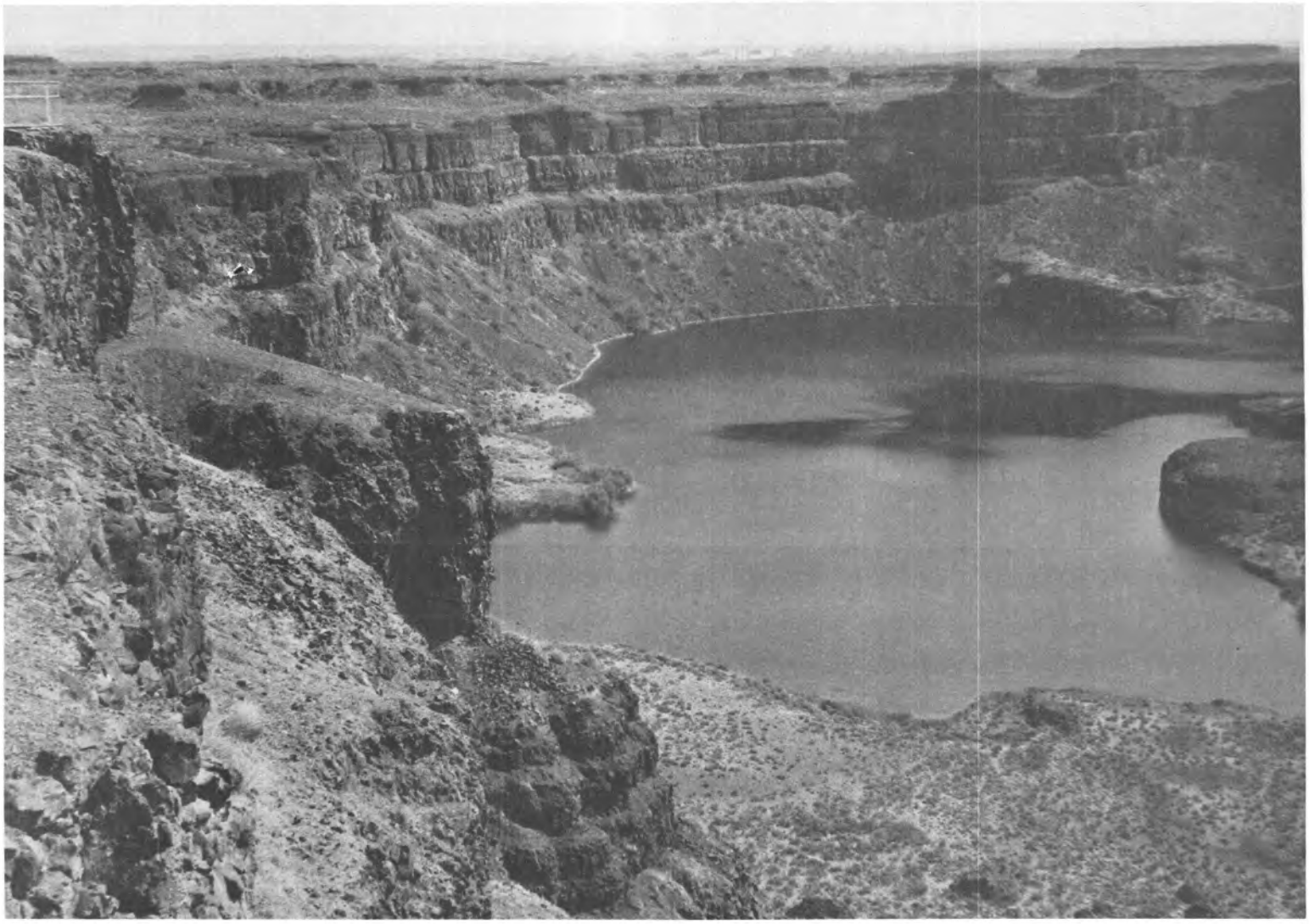

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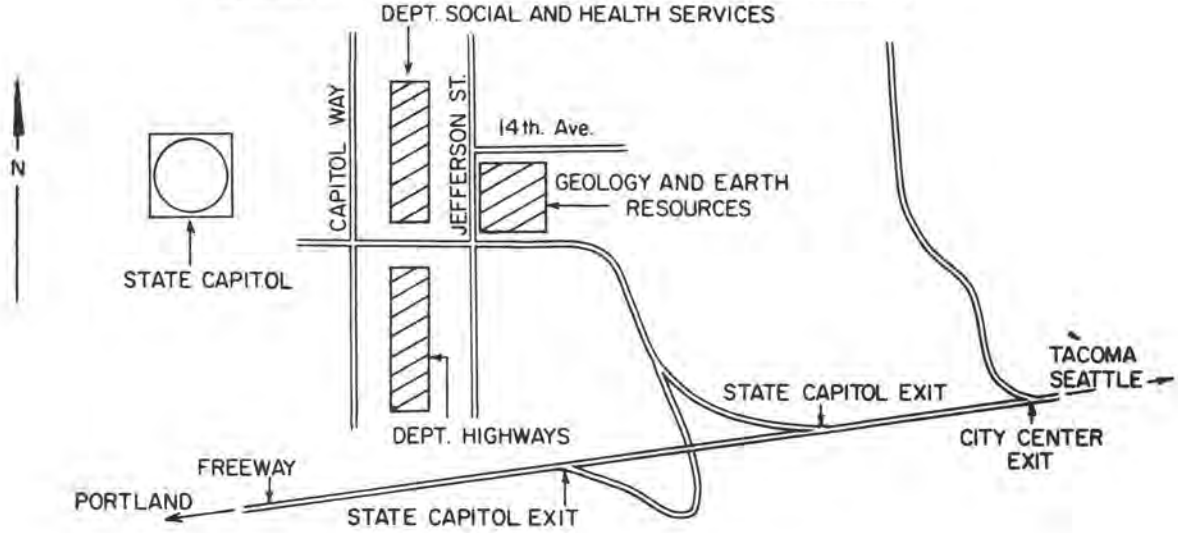

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ORIGIN OF THE GRAND COULEE AND DRY FALLS

by Ted Livingston

Washington State has many interesting geologic features. Among the more outstanding are the Grand Coulee and Dry Falls.

Some 25 million years ago, at the beginning of the Miocene Epoch, the area we now know as the Columbia plateau was a fairly rough mountainous terrain made up generally of granite in the northern part, metamorphic and granitic rocks in the eastern part, and volcanic and sedimentary rocks in the southern and western parts. The streams that drained this area, as well as regions to the west, north, and east, had probably joined on their way to the sea and formed the primeval Columbia River.

Some time during the Miocene Epoch, perhaps only slightly more than 10 million years ago, many large, deep faults developed in the area of the Columbia Basin. These faults, or fissures, were so deep, in fact, that they reached through the crust and into the earth's mantle (50 miles ±). These deep cracks served two functions; one was that they produced a lowering of pressure at great depths allowing the rocks, which were hot enough to melt but were formerly under too great a pressure to do so, to become fluid or molten. Secondly, the cracks served as channelways for the newly molten rock or magma to speed to the surface where it flowed out as a volcanic eruption. Each layer or bed of basalt in the cliff walls of the coulee represents a separate volcanic eruption. As the eruptions continued, the lava flows began to cover the original terrain until in the Grand Coulee area it was completely buried. During the course of these eruptions, as the molten rock came pouring out on the surface, the earth's crust gradually sank down into the space left by the rising magma.

This subsidence of the earth's crust, along with the accompanying outflowing of lava, produced one of the largest basalt-filled basins in the world; in the center of the basin, the basalt probably reaches a thickness of 10,000 feet or more.

Just how long the span of time was between the first and last of these eruptions is not known; however, it probably covered 10 to 15 million years. Likewise, the time differential between individual eruptions in the Dry Falls area is not known; it may have been a few hours, days, weeks, years, or thousands of years.

The lava flows, as they issued from the fissures, spread over the area; they first filled the stream valleys, forming dams that in turn caused impoundments or lakes. As time passed, the streams eventually circumvented the lava dams and found new courses, only to be redammed and pushed out of their channels by new floods of lava. This constant battle between the streams of water and lava floods continued, until eventually the streams were more or less consolidated into one large river, the Columbia, and forced to skirt the north edge of the area of lava flows. The abundant lake deposits of silt, sand, and clay found

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Cover Photo

Dry Falls and the Upper and Lower Grand Coulees were excavated by tremendous discharges of glacial melt waters. After retreat of the floodwaters and reoccupation of its present course by the Columbia River, Dry Falls was left as we see it today, a magnificent series of arcuate escarpments and lake-filled plunge pools.

between different basalt flows, as well as the ancient lava-filled stream channels that can be seen in many of the coulee walls, bear mute witness of the struggle that went on between these two opponents.

The lakes that were formed by the lava dams no doubt served as population centers for plants and animals that existed during that time. It is from the sediments that were deposited in the lakes, and sometimes from the lava and palagonite (a yellowish-brown, claylike material formed by the alteration of volcanic glass) beds that immediately overlie them, that the evidence of that life is found. Fossil leaf impressions, petrified wood, fossil insects, and bones of vertebrate animals have all been found in, or associated with, these ancient lake beds.

One of the most unusual fossils ever found in the Columbia plateau is a mold of a small rhinoceros, commonly known as the "Blue Lake Rhino." It was located in Jasper Canyon in 1935, just below Dry Falls, by a group of hikers. The mold is preserved in pillow basalt that overlies a thin sand bed. Probably the rhino, already dead and lying in a small pond, was covered by molten lava that had chilled when it flowed into the water and formed basalt pillows and palagonite around the rhino without cremating it. The pillows were light enough so they didn't crush the animal but were able to pack in around the carcass sufficiently well to preserve the rhino's shape. Paleontologists made a cast of the mold and reconstructed the rhino.

The basalt flows that make up the Columbia plateau are in themselves somewhat of a wonder. Most magmas, as they pour out of a volcano, form relatively small lava streams that rush down the sides of the volcano, no matter whether it be a strato-volcano like Mount Rainier or a shield volcano like Mauna Loa. The lavas of the Columbia plateau, however, were extremely fluid and spread out in large puddles or lakes. Some geologists who have studied them suggest that several of these lava lakes may have been more than 100 miles across their longest dimension. As the lava flows cooled and solidified, many of them developed a joint system that produced the large vertical columns so noticeable in many of the coulee walls.

As the Miocene Epoch drew to a close, the great fissure eruptions became fewer and fewer, until at last all volcanic activity in the area of the Columbia plateau stopped. Then commenced a period of time when tremendous compressional forces within the earth began to slowly up-fold parts of the plateau into long narrow northwest- to east-west trending ridges called anticlines. Some of these ridges are the Horseheaven Hills, Rattlesnake Hills, Yakima Ridge, Untanum Ridge, Saddle Mountains, and Frenchman Hills. During this time, a great monoclinal fold was pushed up, trending east-west through the Beesley Hills to Ephrata, where its trend became northeast to about Hartline. Simultaneously, a small asymmetrical east-west trending anticline was pushed up in the Soap Lake area. During this period of folding, the whole plateau was tilted slightly to the south by the general uplift of the mountainous area to the north.

The climate during Miocene (25 to 10 million years ago) and Pliocene (10 to 1 million years ago) times was temperate. Such trees as the bald cypress, chestnut, beech, fig, sycamore, tulip tree, magnolia, sassafras, hickory, poplar, birch, elm, and maple all flourished in the coulee area. Toward the last part of the Pliocene the climate began to cool and what we call the ice age began. During this period, vast continental ice sheets slowly pushed their way down from the north country, overwhelming everything in their path except the highest mountain tops. These peaks stuck above the surface of the ice like islands from the sea.

The ice sheet pushed down out of Canada, across the Okanogan Highlands, and into the northern part of the plateau. One lobe advanced as far south as Coulee City, forming an ice dam across the Columbia River at the present site of the Grand Coulee Dam. At this position the ice remained stagnant; that is, the rate of melt was equal to the rate of advance for many years, as evidenced by the large terminal moraine (a more or less sinuous ridge of boulders, gravel, sand, and mud) that formed at the ice front.

This moraine stretches southeastward from the lower end of the Lake Chelan across the Big Bend country almost to the southern end of Grand Coulee, then turns to the northeast and parallels the west rim of the Upper Coulee to the site of Grand Coulee Dam, then turns eastward. As the great ice sheet lay stagnant and then as it began to retreat, tremendous melt-water streams poured down from its icy surface. These streams quickly filled the lake behind the Grand Coulee ice dam to overflowing, the water spilled over the valley rim to the south, and the stage was set for the excavation of the Upper and Lower Coulees of the Grand Coulee.

The waters that overflowed the Columbia Valley at the present site of Grand Coulee Dam formed a river, which flowed along the edge of the glacier, picking up additional water from the many melt-water streams pouring off the ice lobe to as far south as Coulee City. Here, it roared down the steep, south-sloping Coulee monocline, forming a wild cascade 800 feet from top to bottom. The folding of the monocline spread open the joint system of the columnar basalt flows at the crest of the fold, and now the tremendous melt-water river began to attack this weakness. The surging torrent began to pluck chunks of basalt from the face of the fold, and a cataract developed that would dwarf any presently existing waterfall. This waterfall retreated some 20 miles back to the site of Grand Coulee Dam and breached into the Columbia River valley before the ice dam broke, allowing the Columbia River to return to its old course, and drying up the flow in the coulee.

At the same time that Upper Grand Coulee was being excavated by the diverted Columbia River flowing over its retreating waterfall, the river spread out below the Coulee monocline and ran along the toe of the fold to about Soap Lake, where it went raging over the brink of the Soap Lake anticline, forming another foaming torrent. Here again the folding had produced a weakness in the basalt which the turbulent river was quick to take advantage of, and soon a roaring cataract 400 feet high developed. This cataract retreated back upstream to the present site of Dry Falls before the original channel of the Columbia River was freed of ice, allowing the river to return to its normal stream course. When this happened, the once magnificent falls became a series of sheer cliffs with small lakes, such as Dry Falls Lake, Alkali Lake, and Deep Lake, filling the plunge pools at their base (the large deep pool that developes at the base of a falls). When the river abandoned the Grand Coulee stream course, it left a series of lakes—Park Lake, Blue Lake, Lenore Lake, and Soap Lake—in the Lower Coulee. An interesting feature of these lakes is that they become increasingly more saline down the coulee, and Soap Lake, which is at the lower end, is world famous for the medicinal benefits of its salts.

One of the most interesting features of the Grand Coulee, geologically speaking, is how rapidly it was gouged out. This great channelway was dug in just a few thousand years. There are four factors that probably had a tremendous influence on the speed at which the coulees were cut. They are the large amount of water, the jointed nature of the basalt, the soft sedimentary beds between some of the basalt flows, and lastly, the two big folds in the basalt—the Coulee monocline and the Soap Lake anticline.

The large volume of water pouring off the ice sheet formed a river with enormous eroding power. The steep gradients that existed on the faces of the two folds helped the water reach a velocity great enough to pluck blocks of basalt from the bedrock and carry them downstream. The joints in the basalt made it easier for the water to pluck out and remove the basalt. The thin sedimentary beds between some of the flows became planes of weakness that helped speed the retreat of the falls inasmuch as these soft beds were very easily eroded. The churning waters actually undercut the basalt by washing away the sedimentary material. This undercutting, coupled with the inherent weakness imparted to the basalt by the columnar jointing, caused vast sections of the falls to collapse and retreat, just as Niagara Falls is doing today.

NEW DIRECTORY OF WASHINGTON MINING OPERATIONS RELEASED

Information Circular 63, Directory of Washington mining operations, 1977, has been published. The authors, both geologists in our division, are P. Clinton Milne (metallic mining operations), and Charles W. Walker (nonmetallic operations and sand and gravel operations).

Copies of the directory are free upon request. Write to Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA 98504, or call 753-6183.

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The 1977 Directory of Mining Operations is the only updated and complete listing of mining operations and exploration in Washington. In past years, the directory has proven to be a useful tool and guide to the prospector, developer, company official, and layman alike.

The Mining Directory was last published in 1972. The need for a current survey of operations has been evident as shown by the many requests the division has received from the public and industry.

The directory contains entries for companies or individuals, their addresses, mining property locations, and metallic, nonmetallic, or sand and gravel products. Entries dealing with metallic minerals may be in producing, developmental, or exploratory stages. Maps, showing property locations, are included.

By Clint Milne

INVESTIGATION OF TECTONIC DEFORMATION IN THE PUGET LOWLAND, WASHINGTON

by Pamela Palmer and Robert T. Siegfried

Successful terrace correlations between raised marine terrace remnants in western Whatcom and Skagit Counties would make it possible to draw conclusions about any differential vertical movements that may have occurred since the last major regression of relative sea level. During this U.S. Geological Survey funded study, identification of raised marine terraces and strandlines was emphasized for the purpose of correlating laterally separated terrace remnants within each of these counties.

Methods of investigation included terrace profiling, grain-size distribution analysis, ^{14}C-age dating, and surficial geologic mapping. A surficial geologic map of Bay View Ridge, Skagit County, Washington was completed.

Absolute terrace correlations cannot be made due to the paucity of datable materials in the terrace deposits.

Tentative correlations, based on terrace profiling, grain-size distribution analysis, and possible stratigraphic similarities, are made for 20- to 30-foot (6 to 9 meters) and 40- to 60-foot (12 to 18 meters) terrace sequences in Whatcom County (Birch Bay and Lummi Peninsula).

Tentative correlations, based on elevation, are made for 90-foot (27.5 meters), 110-foot (33.5 meters), and 150-foot (46 meters) terrace sequences in Skagit County (Bay View Ridge and south of Mount Vernon).

If the tentative correlations are correct, they imply that little if any measurable differential tectonic and(or) glacio-isostatic uplift has occurred since the last regression of relative sea level in the separate areas of terrace correlation. No statements about relative movement between the two counties can presently be made.

Additional conclusions can be made when results from a pollen analysis of basal peat collected from the 150-foot bog at Bay View Ridge are available. If the peat contains dominant salt marsh or estuarine pollen assemblages, it would establish a former relative sea level at 150 feet, 11,700 years ago at Bay View Ridge.

A question relating to grain size distribution analysis for the identification of fossil littoral sands in glaciated areas was raised during the study.

Friedman's (1967) graph, separating littoral and fluvial depositional environments on the basis of comparing diagnostic statistical parameters, does not apply in much of the study area. However, a new graph was established for the study area based on parameters calculated from samples of known littoral Pleistocene sands.

SELECTED REFERENCES

Friedman, G. M., 1967, Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands: Journal of Sedimentary Petrology, v. 37, no. 2, p. 327-354.

Palmer, Pamela, 1977, Investigation of tectonic deformation in the Puget Lowland, Washington: Washington Division of Geology and Earth Resources Open-File Report OF 77-6, 35 p.

Siegfried, R. T., 1978, Stratigraphy and chronology of raised marine terraces, Bay View Ridge, Skagit County, Washington: Western Washington University M.S. thesis, 52 p.

WASHINGTON GEOLOGIC RESEARCH IN PROGRESS AT COLLEGES AND UNIVERSITIES

We have received some additional information on geologic projects to supplement the main listing that was published in our April newsletter.

Washington State University

- Student Research Project -

Petrochemistry of Mount Baker volcano. Vic Swan. (Ph.D. study).

Eastern Washington University

- Faculty Research Projects -

Geochemistry of granitic rocks of northeastern Washington. Mohammed Ikramuddin.

Fumarole and geothermal ice cave monitoring, Mounts Rainier and Baker. Eugene P. Kiver.

Quaternary geology of the northeastern Columbia plateau. Eugene P. Kiver.

Compilation of computer data base of whole-rock chemical analyses of igneous rocks from Washington. Felix E. Mutschler.

Chemistry of igneous rocks from ocean basins and continents as related to ore deposition. Felix E. Mutschler.

Geologic map of Inchelium quadrangle, Washington. James R. Snook.

Determination of paleomagnetic directions and poles for dated intrusive rocks of northeast Washington: Spirit pluton, Flowery Trail Granodiorite, Starvation Flat Quartz Monzonite, Silver Point Quartz Monzonite, lower Eocene dikes of the Northport quadrangle. W. K. Steele.

The occurrence of olivine nodule bearing alkalic basalts in northern Washington and southern British Columbia. William L. Wilkerson and Harold Lucas (student).

The mineralogy and petrography of olivine nodule bearing basalts in northern Washington and southern British Columbia. William L. Wilkerson and Harold Lucas (student).

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington. E. H. Gilmour.

- Student Research Projects -

Geochemistry of the Loon Lake quartz monzonite and its relation to uranium mineralization at the Midnite mine, northeastern Washington. Kirk P. Kinart.

Geochemistry of granitic rocks from Newport quadrangle, northeastern Washington. Abebe Kassaye.

Behavior of volatile elements in the rocks at the contact of some igneous intrusions of northeastern Washington and its relation to ore mineralization. Louis B. Schipper.

Geochemistry of alaskite and quartz monzonite of Mount Spokane, northeastern Washington, and its relation to uranium mineralization. Roy Bongiovanni.

Geologic hazards in the Spokane quadrangle. Tom Davis.

Patterned ground in the Spokane area. Lee Tallyn.

Palynology of the Badger Lake area, Washington. Rudy Nickmann.

Geology of Turnbull National Wildlife Refuge, Cheney. Christopher E. Sheldon.

Chemistry of the Loon Lake batholith. Walter Nijak.

Genesis of uranium ore deposits at the Gillis lease, Spokane Indian Reservation. Lee C. Nesbit.

Prospecting for magmatic and hydrothermal deposits of uranium and associated elements by computer evaluation of the chemistry and petrogenesis of igneous source rocks. Dennis D. Finn.

Chemical classification of granitic rocks. Granites as paleo-stress gauges. James S. Johnston.

Thickness determinations of Columbia River basalt from total field aeromagnetic data. Ming-Ren Hong.

Sedimentary petrology of the Ringold Formation, Columbia Basin, Washington. Jerry Harbour.

FRIENDS OF MINERALOGY TO SPONSOR MINERAL SYMPOSIUM

Quartz and associated minerals will be the topic of the 4th Annual Northwest Mineral Symposium, sponsored by the Pacific Northwest Chapter of the Friends of Mineralogy. The meeting will be held in Portland at the Ramada Inn South on September 30 and October 1. The Royal Ontario Museum will be among those hosting displays of minerals and crystals.

For more information and registration forms write to Robert J. Smith, Friends of Mineralogy, Box 197 Mailroom, Seattle University, Seattle, WA 98122.

JOHN HITE NAMED CHAIRMAN OF NEXT NWMA ANNUAL CONVENTION

John Hite, regional geologist for Homestake Mining Company, will chair the Northwest Mining Association 84th Annual Convention scheduled for November 30, December 1 and 2, in Spokane.

"The convention theme, The Great Northwest —Resources for Tomorrow, was chosen to express the importance of the Northwest's natural resources to the nation's critical mineral and fuel shortages," according to NWMA President Russell C. Babcock. "Sessions planned for the convention will concentrate on the known and potential mineral and energy sources in the Northwest, as well as their discovery, extraction, and use," he said.

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORTS RELEASED

The following U.S. Geological Survey open-file reports are now available for inspection in our Division of Geology and Earth Resources library:

Index map showing location of Open-File Report 78-354

U.S. Geological Survey, 1978, Aeromagnetic map of the Bellingham area, Washington: U.S. Geological Survey Open-File Report 78-354. Map scale 1:250,000.

Banks, N. G.; Bennett, C. A.; Schmidt, J. M., 1978, Maps of photo lineaments and geomorphological features in the Spirit Lake quadrangle, Washington (A - Photo lineaments; B - Photo geomorphological features): U.S. Geological Survey Open-File Report 78-505. Map scale 1:48,000.

Drost, B. W.; Seitz, H. R., 1978, Spokane Valley-Rathdrum Prairie aquifer, Washington and Idaho: U.S. Geological Survey Open-File Report 77-829, 10 plates, 79 p.

Mast, R. F., 1978, U.S. Geological Survey oil and gas resources investigations program: U.S. Geological Survey Open-file Report 78-303, 77 p.

PUBLISHED USGS MAPS AND REPORTS ADDED TO OUR LIBRARY

The following reports have been published by the U.S. Geological Survey and may be purchased from them; they are available for inspection in our division library:

Tabor, R. W.; Cady, W. M., 1978, Geologic map of the Olympic Peninsula: U.S. Geological Survey Miscellaneous Investigations Map I-944, 2 sheets (east half and west half), scale 1:125,000.

Whetten, J. T.; Laravie, J. A., 1976, Geology of Chiwaukum 4 N.E., Washington: U.S. Geological Survey Map MF-794, scale 1:24,000.

Whetten, J. T.; Waitt, R. B., Jr., 1978, Preliminary geology of the Cashmere quadrangle, Washington: U.S. Geological Survey Map MF-908, scale 1:24,000.

NEW TOPOG MAP INDEX FOR WASHINGTON

A new index showing 1009 topographic maps covering most of Washington is now available from the U.S. Geological Survey. The map index includes eight pages of text and a map of the state showing the extent of published topographic mapping.

Copies of the "Index to Topographic Maps of Washington" are available free from the Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225. Maps described in the index may be purchased from the same address.

YOUR STATE GEOLOGIST REPORTS

The era of forensic geology seems to have arrived. The triggering mechanism, in our area anyway, seems to have been the advent of nuclear

power stations. I have watched and listened to, with considerable interest, the discussions of both sides on a plant-siting controversy as they presented their interpretations of the same data. I think this has done much to stimulate the profession so far as environmental geology is concerned. We are seeing geologists putting their neck on the block as it were, and making hard decisions that have the potential to affect lives. I think this is great, with one reservation, and that is that we keep our arguments on a professional level and base them on honest interpretation of available data and not on emotions. It certainly is bringing the profession a lot of public awareness that has not existed in the past. This is reflected by the increased number of requests our division gets from local planning groups for help with problems that are at least partially related to geology.

The geologic profession has a part to play in planning for land development and it is important that we help in the decision-making process by giving the decision makers the best and most factual data available in a nontechnical form or format that they can understand. In this process, personal predjudices must be put aside and we must be willing to accept a reasonable risk and not say "no" to any proposal that appears to have some risk involved. To illustrate this, I would cite the case of a county that wanted to build a road in a mountainous area. A geologist from a state agency (not ours) advised them that the road was crossing a slide and the road should be moved across the canyon. The alternate route would have cost several times as much to build, so the county blindly kept on building at the original site. Well, as it turned out, the slide was shallow, something the geologist should have recognized. The only problem the slide causes is that each spring an excessive amount of debris piles up in the ditch, so the ditches must be cleaned every year. This is a small expense compared with changing the alignment of the road. The problem, as I see it, was that the geologist reacted emotionally rather than examining the available data before making his decision. The only thing he saw was a slide and he didn't stop to analyze what its real impact might be. His first and only impulse was "slide, avoid it." A careful, thoughtful investigation would have revealed that probably the only problem would be excessive rock debris in the ditch with minimal added cost for maintenance.

Ted Livingston

U.S. GEOLOGICAL SURVEY 7½-MINUTE TOPOGRAPHIC QUADRANGLES
(Maps received in the division library since April 1, 1978)

Name	New edition	Photo revised	Latitude (indicates southeast corner)	Longitude	County
Eastsound	1977		48°37'30"	122°52'30"	San Juan
Granite Point (formerly Bishop)	1964	1975	46°30'00"	117°15'00"	Garfield; Whitman
Kirby	1964	1975	46°30'00"	117°22'30"	Garfield
Liberty Lake	1973		47°37'30"	117°00'00"	Spokane
Lopez Pass	1973		48°22'30"	122°45'00"	San Juan
Orchards	1961	1970; 1975	45°37'30"	122°30'00"	Clark
Washougal	1961	1970; 1975	45°30'00"	122°15'00"	Cowlitz

July 1976

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