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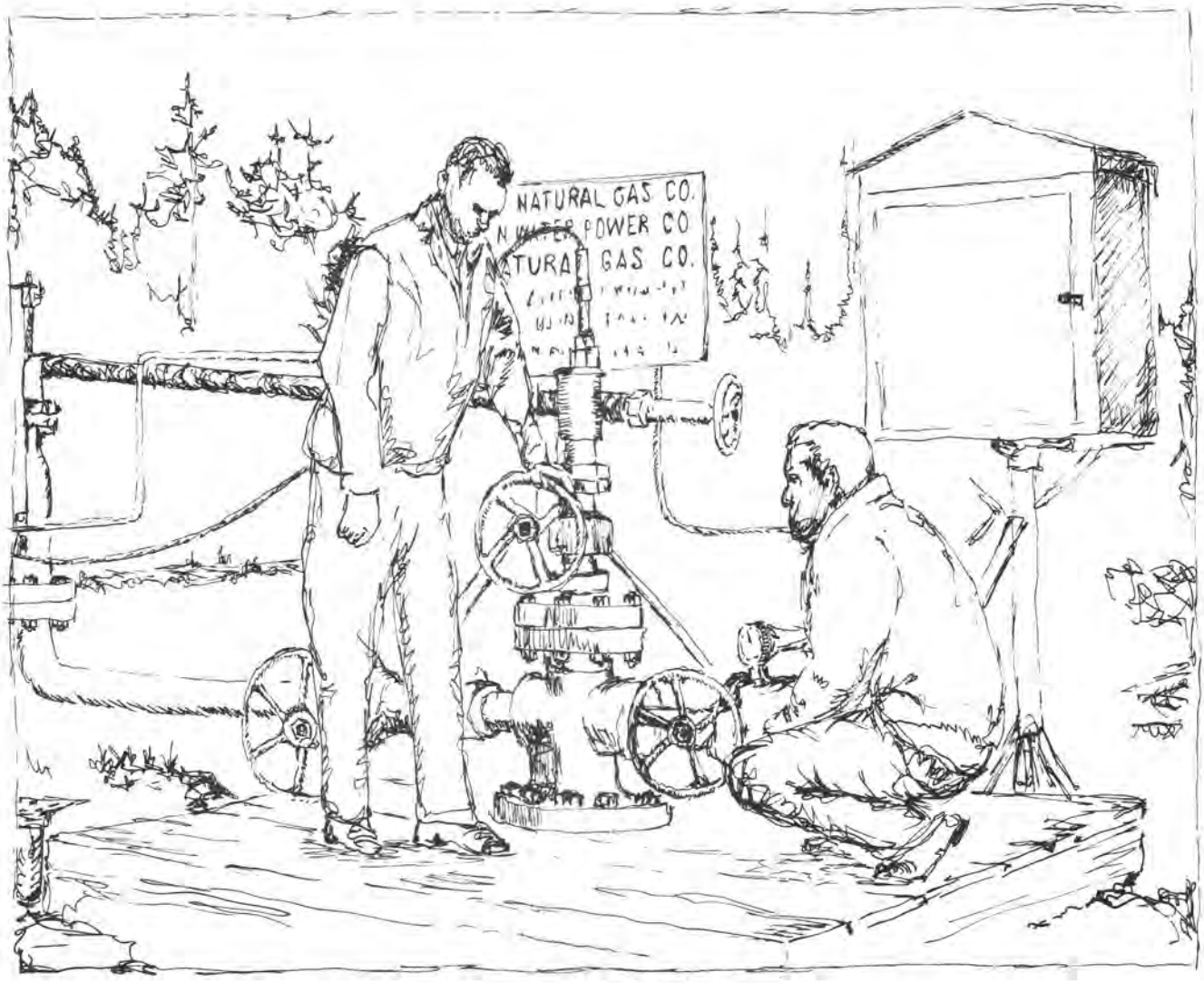

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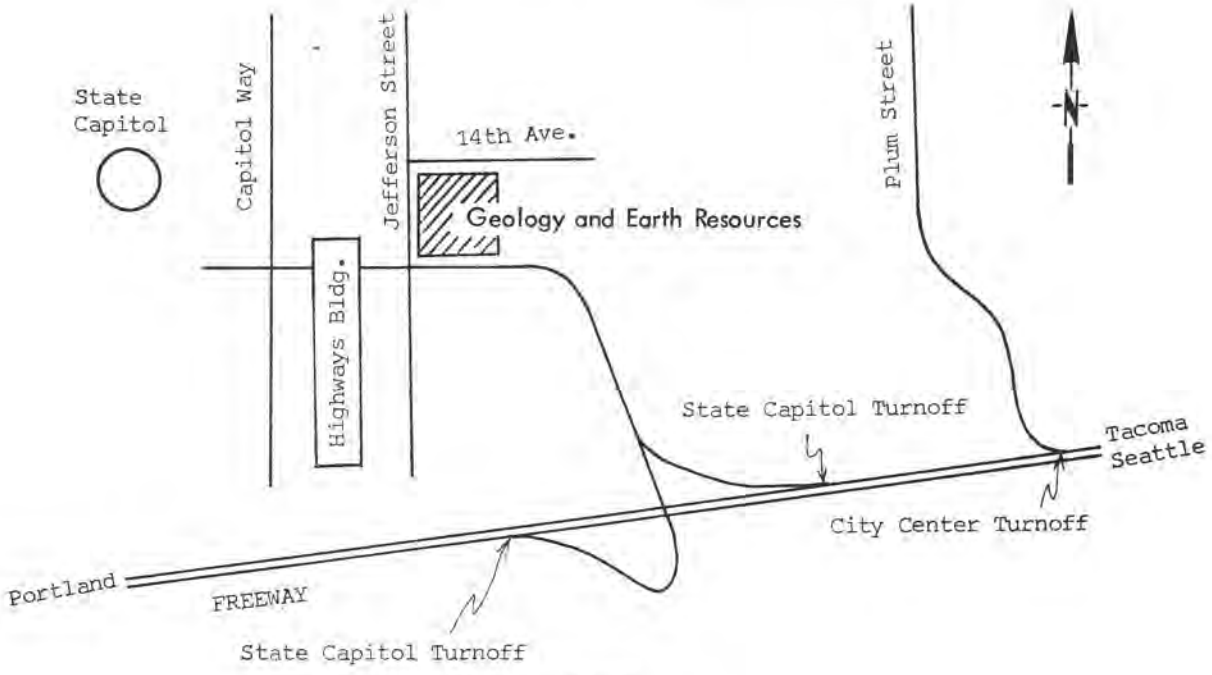
LOCATION MAP

DIVISION OF GEOLOGY AND EARTH RESOURCES



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COVER

Injection well at gas storage site. A spur pipe carries the gas to the storage project from the pipeline. Huge compressors powered by natural gas engines force the gas into the ground; others will pump it out as the gas is needed. Drawing by Doyal F. Foster.

JACKSON PRAIRIE GAS STORAGE PROJECT, CHEHALIS, WASHINGTON[1/]

by

Fred H. Wurden and Donald M. Ford[2/]

Few people realize the volume of storage space required to store natural gas in the amount used by consumers today. The Jackson Prairie underground gas storage project is the only underground gas storage project in the Northwest. Its capacity is currently in excess of 26 billion cubic feet, which if contained at normal temperature and pressure, would require a container approximately 1 mile in diameter and 1,187 feet in height, or about equal to the volume of 388 King Dome Stadiums. Depending upon the severity of the weather, average withdrawal of gas from storage

1/ Modified from Oregon Dept. of Geology and Mineral Industries, 1976, Oil and Gas Investigations 5, p. 37-41.

2/ Fred H. Wurden, Geological Engineer, Quilcene, Washington; Donald M. Ford, Assistant Supervisor, Washington Division of Geology and Earth Resources.

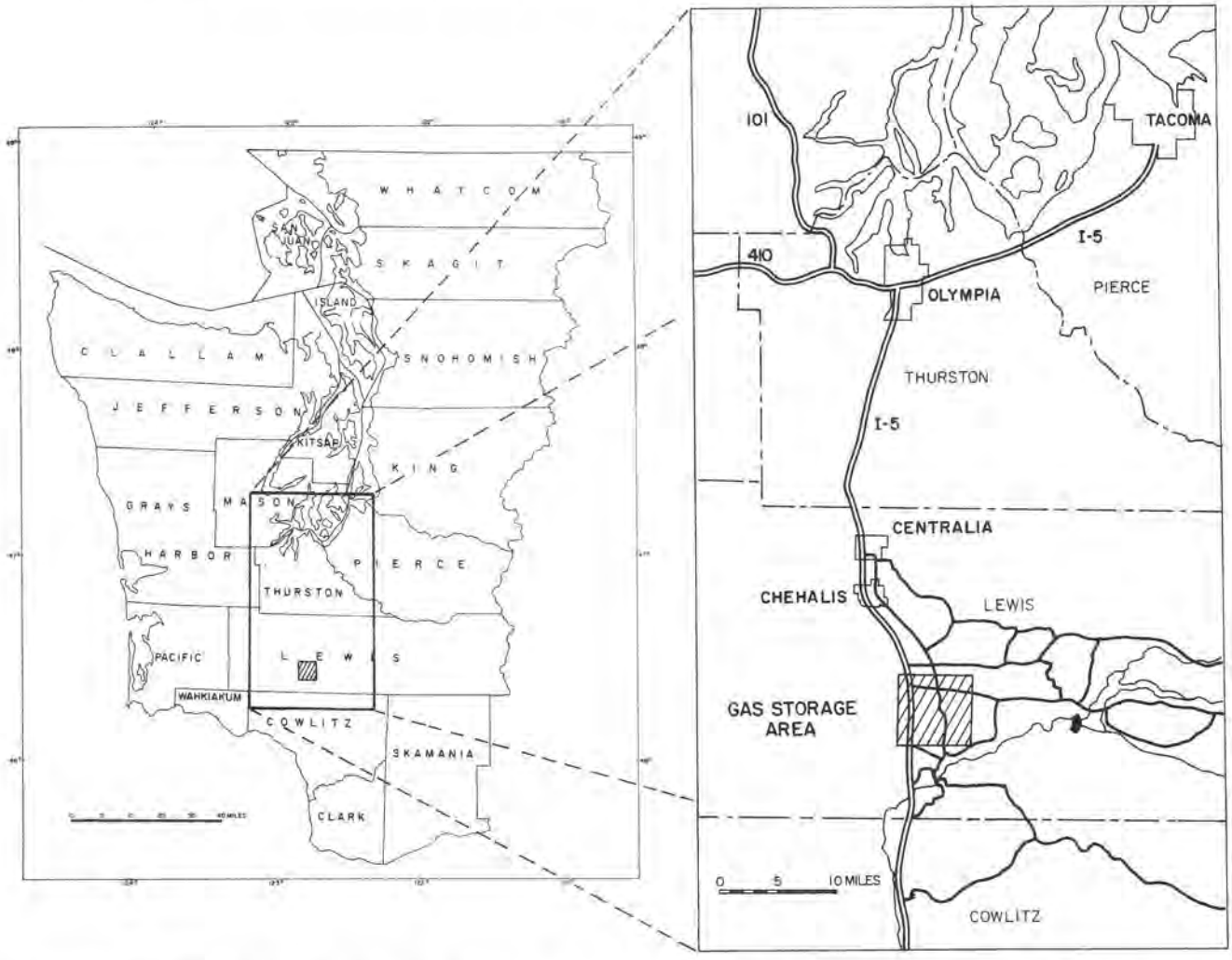

FIGURE 1.—Location of the Jackson Prairie gas storage project, T. 12 N., R. 1 W., Lewis County, Washington.

TABLE 1.—Pleasant Valley Oil and Gas, Washington Water Power Company, Washington (Natural Gas Company and El Paso Natural Gas Company) Jackson Prairie Storage Unit Well No. 1

Geologic data

Formation	Depth (ft)	Elevation (ft)	Thickness (ft)
Logan Hill (Pleistocene)	Surface		480
Lincoln (Oligocene)	480-1737	- 47	1257
Storage Zone 1	1270-1380	- 743	110
Skookumchuck (upper Eocene)	1737-7380	-1210	5643
Storage Zone 2	1737-1878	-1210	141
Goble Volcanics	1878-2508	-1351	130
Storage Zone 3	2508-2540	-1981	32
Storage Zone 4	2607-2628	-2080	21
Storage Zone 5	2643-2660	-2116	17
Storage Zone 6	2664-2740	-2137	76
Storage Zone 7	2780-2865	-2253	85
Storage Zone 8	2892-2904	-2465	12
Storage Zone 9	2918-3182	-2391	264
Northcraft	7380	-6853	Not penetrated

Porosity-Permeability

Depth (ft)	Perm. (md)	Porosity (percent)	Saturation Oil (percent)	Saturation Water (percent)	Percent gas Bulk vol.
1587	19.0	38	0	95	2.0
1594	0.0	29	0	82	5.0
1600	7.5	31	0	92	3.0
1663	52.0	23	0	93	1.7
1671	61.0	47	0	92	3.6
1678	41.0	23	0	64	1.1
1744	500.0	36	0	93	2.7
1815	NR	38	0	81	7.2
1836	1017.0	37	0	80	7.0
1862	550.0	38	0	79	8.4
2515	1280.0	38	0	84	16.0
2527	121.0	37	0	65	35.0
2534	207.0	35	0	70	30.0
2588	9.4	33	0	86	14.0
6042	2010.0	29	0	91	9.0
6058	413.0	33	0	75	25.0

during an average January is approximately 150 million cubic feet per day.

The Jackson Prairie underground gas storage project was initiated in the early 1960's by Washington Natural Gas Company, the Washington Water Power Company, and Northwest Pipeline Corp. The 3,000-acre storage field is located 9 miles southeast from the city of Chehalis in western Lewis County (fig. 1). The geologic structure was discovered by Pleasant Valley Oil and Gas Company and J. W. Tanner while drilling for oil and gas production in 1958. The structure was found to be nonproductive, so the company abandoned its "Guenther No. 1" test hole at 8,015 feet. The hole (re-named Storage Unit No. 1) was re-entered in November 1963 by the present operators to test for gas storage potential (see table 1).

Increased use of natural gas in the Northwest for domestic and industrial needs resulted in construction of the present extensive pipeline systems. Because pipelines are designed to carry the anticipated average-demand volume, cold weather spells make it necessary to interrupt service to certain industrial customers, since it is not economically feasible to design pipe lines for carrying peak loads that occur only a few weeks of the year. Local gas storage facilities assist in smoothing out the load peaks, particularly underground storage where very large amounts of gas can be held.

Most of the 366 underground storage projects in the United States utilize depleted oil or gas reservoirs; however, the Jackson Prairie project used brackish-marine aquifers contained in the upper Eocene Skookumchuck Formation. Fifty other underground gas storage projects in the United States store gas in brackish and saline aquifers. It was found that the sandstone at Jackson Prairie was saturated with brackish water, so that some of it had to be pumped from the "dome" structure in order to create storage for gas. Water removal wells are located around the perimeter of the project to withdraw water from the lower portion of the structure, thus creating a cap of void space at the crest of the "dome." Operators of the storage project have a permit from the State Department of Ecology to release 50,000 gallons of brackish water a day into the Cowlitz River at favorable flow conditions.

The Jackson Prairie project lies in the south-central part of the Cowlitz basin as shown on the location map (fig. 1). The basin is believed to be underlain by brackish marine and nonmarine sedimentary rocks to depths in excess of 7,000 feet. Subsurface conditions of the area are generally depicted on the cross section shown in figure 2. Some modifications were made to figure 2 for purposes of this report. The oldest rocks known to underlie the basin are pillow lavas, volcanic breccia, and interbedded marine sediments of the McIntosh Formation.

According to Snavely and others (1958), the Northcraft Formation conformably overlies the McIntosh Formation. The Northcraft consists chiefly of volcanics and nonmarine rocks and is believed to be equivalent to the lower part of the Goble Volcanics. Late Eocene volcanics in the Chehalis-Centralia area are gabbroic and basaltic sills and dikes intrusive into the Skookumchuck Formation. These volcanics separate the top three storage zones from the lower zones. The age of the volcanics in this area is late Eocene to early Oligocene. Farther south, near Castle Rock and in northwestern Oregon, these basaltic flow rocks issued from vents to the east of the Tertiary marine basin and attain their maximum thickness along the Columbia River. Late Eocene flows at Castle Rock are correlated with the Goble Volcanics.

Lenticular strata of sandstone, siltstone, shale and interbedded coal seams form the Skookumchuck Formation. The Skookumchuck overlies older rocks with angular unconformity indicating an intervention of uplift and temporary withdrawal of the sea. These beds were laid down in a brackish- to fresh-water lagoonal environment in the area of the storage project. Sandstones in the Skookumchuck closely resemble those of its age equivalent, the Cowlitz Formation. Sandstones are fine to medium grained, micaceous,

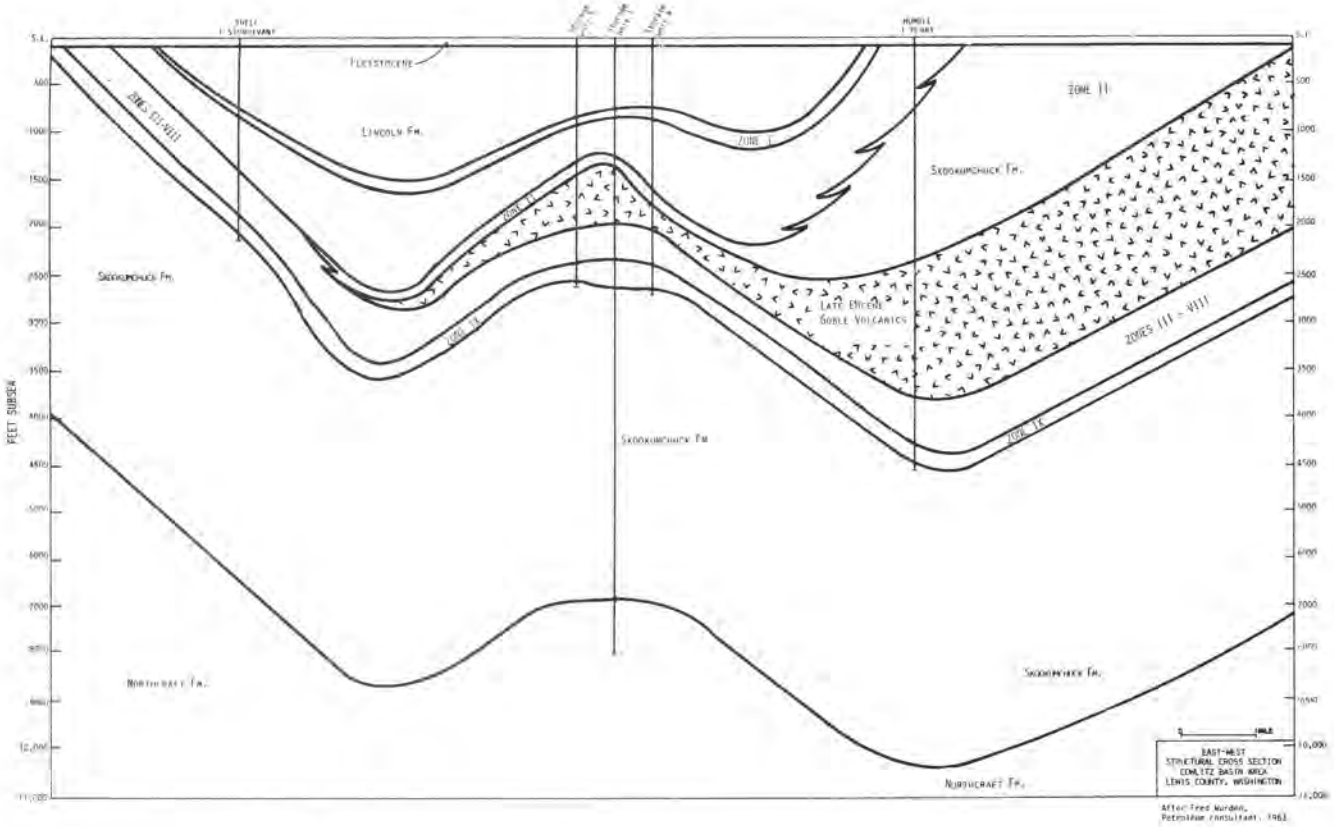

FIGURE 2.—East-west structural cross section, Cowlitz basin area, Lewis County, Washington.

carbonaceous, basaltic, and arkosic. Sands of the Skookumchuck are the storage reservoirs for the Jackson Prairie project. Porosity of these sandstones ranges from 5.3 to 35.2 percent in the Cowlitz basin. Permeability ranges from 1.4 to 3,506 millidarcies (Snavely and others, 1958). Permeability in Zone II storage reservoir ranges from 1 to 3 darcies and the average weighted porosity is 36 percent (Hoglund, 1976).

The Lincoln Creek Formation conformably overlies the Skookumchuck in the central Cowlitz basin. It consists of shallow marine deposits composed of sand, silt, and shale. Zone I is a fine- to very fine-grained sandstone located in the Lincoln Creek Formation and was one of the zones tested early in the storage investigations. It is not being used for storage.

Sandstone Zones 1 through 9 are separated by shale, siltstone, and coal beds, thereby effecting a seal against vertical migration of the stored gas. Zone 1 is in the Lincoln Creek Formation, Zone 2 is in the uppermost Skookumchuck Formation above late Eocene volcanics. Zone 2 is subdivided into subzones A, B, and C, which are separate sandstone bodies. The storage reservoir presently consists of Zones 2A, 2B, and 2C. They are located approximately 1,800 feet beneath the ground surface, initially saturated with salt water. Zones 3 through 8 lie just beneath late Eocene volcanics in the Skookumchuck Formation. Zone 9 consists of a massive sandstone several hundred feet thick. It is underlain by several thousand feet of Skookumchuck sands, shales, siltstones, and coal beds in the central Cowlitz basin.

A total of 76 wells have been drilled at Jackson Prairie since the storage project began. Storage capacity developed in the upper zones now totals in excess of 26 billion cubic feet. Additional exploration and testing indicates another 30 billion cubic

feet of storage may be developed in the deeper zones.

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U.S. GEOLOGICAL SURVEY CURRENT ACTIVITIES IN WASHINGTON, 1977

MINERAL RESOURCES ACTIVITIES

Mineral resources of Spirit Lake quadrangle, N. G. Banks. Study samples collected; prepare for field work in northwest corner of quadrangle, including geologic mapping, geochemical sampling, and alteration study. Also, during project work, the exploration and development of ore deposits will be observed.

Geothermal resource evaluation, J. R. Swanson. Continue to gether resource data and handle retrieval requests. Included this year will be developments of map-plotting capabilities, data-manipulation routines, and on-line computer routines.

Togo Mountain quadrangle, R. C. Pearson. Limited amount of time will be spent on petrography and preparation of quadrangle maps for publication.

Indian lands resource studies, W. P. Puffett. Preparation of administrative report for Yakima Indian Reservation summarizing unpublished and published mineral resources information and the recommendations for further work in order to evaluate and develop Indian land mineral resources. Report prepared jointly by USGS and USBM personnel.

ENERGY RESOURCES ACTIVITIES

Geology and geochemistry of coal, V. E. Swanson. Collect and analyze an additional 1,500 coal samples in order to expand and maintain a complete, modern, and high-quality data base on the chemical composition and quality of coal in the U.S. Date will be supplied to meet immediate environmental and technological needs to government, academic, and industry groups dealing with the development of coal resources.

Trace-element geochemistry related to coal mining, usage, and disposal, Peter Zubovic. Sample six more power plants, including some using only eastern coal.

Midnite Mine uranium studies, J. T. Nash. Complete report on biogeochemistry of uranium in pine needles, geochemical study of uranium in granitic rocks, and detailed geologic map (1 inch = 500 feet) and configuration of the intrusive contact of Midnite Mine area.

Vein and disseminated deposits of uranium, J. T. Nash. New project just underway will conduct reconnaissance geology and sampling of plutons in northeastern Washington for favorable source and host rocks of uranium.

Trace-metal geochemistry of offshore marine sediments, M. H. Bothner. Results of a study dealing with flux of mercury plus nutrients from contaminated sediments in Puget Sound will be published.

Marine geochemical studies, J. L. Bischoff. Complete Willapa Bay report on hydrocarbon in sediments and the study of amino acids in terrace deposits.

Make a comparison study of the hydrocarbon geochemistry of sediments in Willapa Bay and Grays Harbor to evaluate the effects of pollution and establish an environmental baseline.

Oregon-Washington onshore-offshore, P. D. Snavely. Collect approximately 2,500 km of gravity, magnetic, and both multichannel and high-resolution seismic reflection on Oregon and Washington OCS. Continue interpretation and compilation of geologic and geophysical data from various OCS sources and petrographic and paleontological studies on samples from OCS wells. Prepare a prenomination report for proposed Sale 53 on the Oregon and Washington continental margin.

Puget Sound, F. H. Nichols. Summarize data from bottom samples collected in Puget Sound between 1963 and 1977, in an interpretation of long-term changes in structure of continental-shelf depth benthic community.

Pacific Coast sedimentology, H. E. Clifton. Complete studies of sand transport in Willapa Bay and on the mechanics of beach sedimentation. Continue facies and analysis of estuarine deposits and expand studies of hydrodynamic effects of waves on sedimentation. Studies will be initiated on distribution of spilled oil in nearshore systems and the relationship to beach and nearshore processes.

Environmental geologic studies of the Oregon and Washington continental shelf and margin, H. E. Clifton. The base maps and bibliography of all data are essentially complete. Work will begin on compilation of sediment transport, thickness and textural data, bedrock geology relevant to geologic hazards, faulting, age, and lithology of all sea-floor sediments.

ENVIRONMENTAL GEOLOGY ACTIVITIES

Geology of Olympic Peninsula, W. M. Cady. Complete report on lead-isotope composition of volcanic rocks and on geology of Olympic Peninsula, including a geologic map at 1:150,000 scale.

Quaternary map of the U.S., G. M. Richmond. Map compilation from various sources of Quaternary deposits, including volcanic rocks, of conterminous U.S. is presently being done by State Geological Surveys and university personnel. Ultimate publication will be a colored map at 1:2,500,000 scale.

Cape Flattery area, P. D. Snavely. Field check geologic maps of four 15-minute quadrangles, and prepare a detailed reconnaissance geologic map of north half of La Push and Forks quadrangle. Complete interpretation of aeromagnetic survey of project area, and conduct detailed geologic mapping within the lower to middle Eocene Crescent Formation.

Puget Sound urban studies, H. D. Gower. Complete interpretation of seismic profiles from northern Puget Sound; collect and interpret profiles from southern Puget Sound; map unconsolidated deposits and bedrock geology of Port Townsend 1:100,000 sheet; and complete report on channel changes of Skagit River (1941-1974).

Wenatchee 2° quadrangle, R. W. Tabor. Continue mapping Levenworth, Chelan, and Snoqualmie Pass quadrangles, and prepare Wenatchee 1:100,000-scale map and text for publication. Other work will be petrographic studies and modal analysis, mineral separation, K/Ar and fission-track dating of rock samples and compilation of Snoqualmie Pass and parts of Chelan quadrangles.

Tectonic analysis, Washington, K. F. Fox, Jr. Review and compile published and unpublished data; conduct field checks and field conferences to delineate major petrotectonic assemblages and tectonic features on maps at appropriate scales; summarize tectonic history; and identify areas where additional mapping is needed.

Volcanic hazards, D. R. Crandell. Prepare reports on the unconsolidated volcanic deposits of late Quaternary age at Mount St. Helens, and on the extent and nature of hydrothermal alteration in rocks of Mount Rainier and Mount Baker volcanoes.

Volcanic hazards overview, D. R. Mullineaux. Complete report on volcanic hazards at Mount St. Helens for publication.

Lava ridges and rings, C. A. Hodges. Project will be completed with the publication of a journal article presenting in detail the hypothesis proposed to explain the unique ring structures of the Columbia Plateau.

GEOCHEMISTRY AND GEOPHYSICS

Genesis of basalt, T. L. Wright. Continue study of Columbia River basalt, including regional mapping, major- and trace-element geochemical studies, and paleomagnetic and isotopic studies. Begin publishing information on the chemical character, stratigraphic relation, and petrogenesis of Columbia River basalt, and the results of an experimental study of melting relations of basalt of the Ice Harbor unit at pressures from 1 atm to 20 kb.

Regional volcanology, R. L. Smith. Compile and complete for publication the Oregon-Washington volcano map at 1:1,000,000 scale.

Volcanic ash chronology, R. E. Wilcox. Continue to develop methods for identifying volcanic ash beds that are useful as time-stratigraphic markers in Quaternary or older deposits in order to judge the degree of hazard from future volcanic ash falls in areas of urban and industrial development.

Columbia River basalt, D. A. Swanson. A map of Yakima Basalt in the Spokane, Ritzville, and Wenatchee quadrangles will be completed. Reports dealing with chemical correlation of the Yakima Basalt flows, intracanyon flows along the Snake River, and the revised stratigraphy of the Columbia River basalt will be prepared.

Data processing and analysis, R. H. Godson. Complete aeromagnetic map of northern Washington at 1:62,500 scale. Continue to devise new and better methods of data processing of geophysical data and develop a generalized system of computer programs and procedures for data reduction and analysis.

Theoretical analysis of magnetic data, R. J. Blakely. Develop techniques for interpretation of magnetic anomaly data and apply to geologic problems in western Oregon, Washington, and California. Techniques will be applied to depth-to-source calculations, refinement of geomagnetic timescale, and determination of lateral variations in magnetization.

Magnetic observatory and field data processing and analysis, R. J. Main, Jr. Continue the processing and analysis of data from magnetic field stations throughout the U.S. and from nine permanent magnetic observatories. Data are made available through World Data Center A for use in land surveying, space and upper atmospheric research, R&D testing laboratories, national defense, chart compilation, international exchange, geophysical exploration, navigation, etc.

Geomagnetic systems and development, F. C. Frischknecht. Complete processing backlog of digital data for deposit in World Data Center A in order to organize and improve techniques and investigate loss of digital data in recording and processing phase.

Geologic investigations of surface-thermal manifestations, J. D. Friedman. Continue to test and evaluate aerial and satellite infrared-scanning techniques and concomitant ground observations in geothermal studies.

Mineral exploration by gamma-ray spectrom-

etry in crystalline rocks, J. A. Pitkin. Complete analysis and computer reduction of gamma-ray data from Midnite Mine/Togo Formation outcrop and alaskites of Mount Spokane and begin writing up results.

EARTHQUAKE STUDIES

Seismological observatories (Newport, Wash.), Harry Whitcomb. Operation and maintenance of a national and worldwide network of observing and reporting systems will be continuing at the various observatories. Data serve as input for government research and outside scientific programs.

Seismic review and data service, R. P. McCarthy. Continue quality control management and seismograms generated by World-Wide Standardized Seismograph Network (WWSSN) comprised of 113 active stations located in 62 countries. Adapt review data to ADP formats so that the entire 15-year file will be on tape or cards to supplement the users' file.

Global volcano surveillance net, (Mount Baker), D. H. Harlow. Continue to collect and interpret data on seismic and ground-tilt phenomena associated with volcanic eruptions in order to forecast volcanic eruptions and understand the fundamental mechanics of the eruptive processes; publish the significant results.

NRC (Nuclear Regulatory Commission) site seismicity, S. R. Brockman. Review and evaluate Skagit County seismological report submitted to NRC by an electrical power company seeking permit to construct a nuclear power facility. Review entails evaluation of completeness of data and validity of conclusions.

U.S. seismogenic zones, J. I. Ziony. Evaluate the tectonic and seismic framework and identify earthquake source zones of the Gulf of Alaska and west coast OCS as a basis for assessing the seismic risk of possible petroleum-bearing areas of the OCS.

Earthquake-hazard evaluation in the Pacific Northwest, S. W. Smith and R. S. Crosson, University of Washington. Investigations include continuation of acquisition and analysis of seismic network data; routine explosion monitoring for seismic velocity changes; preparing an analysis and summary of recent Puget Sound seismicity; completing investigation of three-dimensional crustal structure modeling; and initiating a study of near-field ground motion from earthquakes using a finite element method.

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(Cooperative efforts and open-files included)

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U.S. Geological Survey, 1976, Aeromagnetic map of northern and eastern parts of the Puget Sound area, Washington: U.S. Geological Survey Open-file Report 77-34.

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Whetten, J. T.; Laravie, J. A., 1976, Preliminary geologic map of the Chiwaukum northeast quadrangle, Chiwaukum graben, Washington: U.S. Geological Survey Map MF-794.

Whetten, J. T., 1977, Sedimentology and structure of part of the Chiwaukum graben, Washington [abstract]: In Geological Society of America Abstracts with Programs, v. 9, No. 4, p. 527.

Whetten, J. T.; and others, 1976, New dates and their significance from the San Juan Islands, Washington [abstract]: In Geological Society of America Abstracts with Programs, v. 8, No. 6, p. 1166.

Yates, R. G., 1976, Geology of the Deep Creek area, Washington, and its regional significance: U.S. Geological Survey Open-file Report 76-537.

In addition to these reports, summaries of significant results of most current projects are contained in U.S. Geological Survey Professional Paper 1000.

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORTS

The following open-file reports and maps by the U.S. Geological Survey are now available for inspection in the division library in Olympia:

Schlumberger soundings in the Kitsap Peninsula area, Washington, by Dallas B. Jackson and Robert J. Bisdorf, 1 pl., 74 p. Report No. 77-290.

Biogeochemical prospecting for uranium with

conifers—Results from Midnite mine area, Washington by J. Thomas Nash and Frederick N. Ward, 1 pl., 23 p. Report No. 77-354.

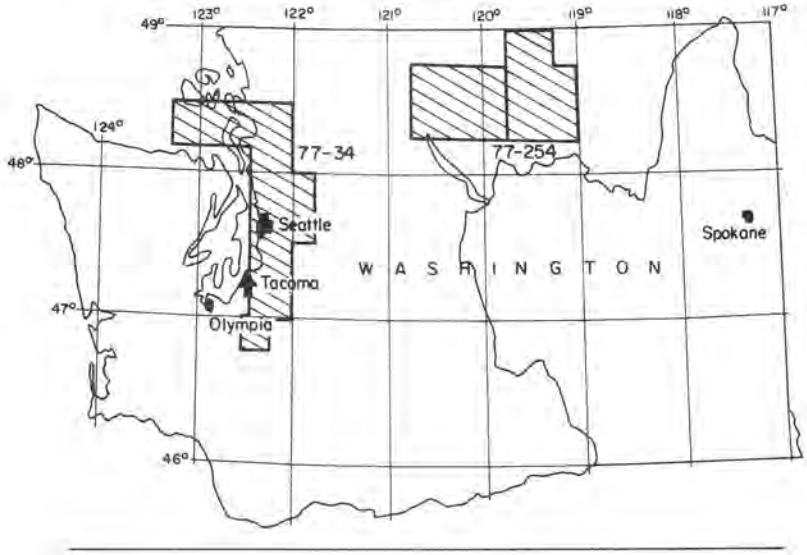
Preliminary geologic map of the Togo Mountain quadrangle, Ferry County, Washington, by Robert C. Pearson, map scale - 1:62,500. (Division library has reproducibles.) Report No. 77-371.

A probabilistic estimate of maximum acceleration in rock in the contiguous United States, by S. T. Algermissen and David M. Perkins, 45 p. Report No. 76-416.

Aeromagnetic map of part of northern Washington, by U.S. Geological Survey, 2 pls., map scale - 1:62,500. Report No. 77-254.

Aeromagnetic map of northern and eastern parts of the Puget Sound area, Washington, by U.S. Geological Survey, 1 pl., map scale - 1:125,000. Report No. 77-34.

Index map for open-file aeromagnetic maps



U.S. GEOLOGICAL SURVEY 7½-MINUTE TOPOGRAPHIC QUADRANGLES
(Maps received in the division library since April 1, 1977)

Name	New edition	Photo revised	Latitude (indicates southeast corner)	Longitude	County
Canyon Lake	1972		48°45'00"	122°00'00"	Whatcom
Cape Disappointment	1949	1973	46°15'00"	124°00'00"	Pacific
Clayton	1973		47°52'30"	117°00'00"	Stevens, Spokane
Deer Park	1973		47°52'30"	117°22'30"	Spokane
Edwall	1973		47°30'00"	117°52'30"	Lincoln
Ford	1973		47°52'30"	117°45'00"	Stevens
Fourmound Prairie	1973		47°45'00"	117°37'30"	Stevens, Spokane
Kendall	1972		48°52'30"	122°07'30"	Whatcom
Mica Peak	1973		47°30'00"	117°00'00"	Spokane
Oysterville		1973	46°30'00"	124°00'00"	Pacific
Reardan East	1973		47°37'30"	117°45'00"	Lincoln, Spokane
Waukon	1973		47°30'00"	117°45'00"	Lincoln, Spokane
Willy Dick Canyon	1957	1973	46°15'00"	120°52'30"	Yakima
Yesmowit Canyon	1957	1973	46°22'30"	120°52'30"	Yakima

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