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PALEOMAGNETISM OF BASALT FLOWS
NORTHCENTRAL DESCHUTES-UMATILLA PLATEAU, OREGON

Saleem M. Farooqui* and Donald F. Heinrichs**

The Columbia River Basalt consists of dozens of seemingly identical flows of basalt covering thousands of square miles of Oregon, Washington, and Idaho. For years, detailed mapping of the units relied almost entirely on subtle petrographic distinctions, the presence or absence of interbeds, and actual walking along contacts in the field. Eventually two divisions were recognized: Yakima Basalt and Picture Gorge Basalt. Further detailed work in southeastern Washington revealed distinctive and laterally continuous flows within the Yakima Basalt.

In recent years, geochemical and geophysical techniques have been used to supplement more traditional geologic approaches, allowing geologists to map with much greater precision. The paleomagnetic technique described in this article illustrates how new technology is assisting the geologist in his work.

Introduction

Paleomagnetic and radiometric age determinations by Cox (1969), and subsequent investigations, have established a world-wide time reversal history of the geomagnetic field. Cox and Doell (1964) indicated that the polarity reversal of the main dipole occurred at characteristic intervals of about one million years during the entire Tertiary period. Additional studies by Doell and Cox (1962) further indicate that the measurements of remanent magnetism provide a basis for stratigraphic correlation of rocks suitable for paleomagnetic analysis. Holmgren (1969), Campbell and Runcorn (1956), Rietman (1966), and Kienle (1971) investigated the remanent magnetism of the Yakima Basalt. Their investigations show

* Shannon & Wilson, Inc., Portland, Oregon

** National Science Foundation, Washington, D.C.

that some flows, such as the Roza Basalt, Priest Rapids Basalt, Pomona Basalt, and Frenchman Springs Basalt, have unique remanent magnetic directions which serve as paleomagnetic marker horizons. Accordingly, a study of remanent magnetization was conducted by Shannon & Wilson (1973) to assist in regional and local geologic correlation of the basalt flows and to provide information for theoretical magnetic models.

The use of paleomagnetic data to correlate rocks is based on two independent phenomena. The first arises from changes of the Earth's magnetic field with time. The second is created by the fact that almost all igneous and some sedimentary rocks become permanently magnetized in the Earth's field at the time they are formed. The time changes of the geomagnetic field result in a bimodal distribution of paleomagnetic directions. One group of magnetic declinations centers about geographic north; this group is generally termed normal, or normal polarity. The other group, with southward declinations, is generally termed reversed polarity. This bimodal distribution is of the greatest stratigraphic interest. Rocks of similar age from all over the world show the bimodal distribution. It is now clear that volcanic rocks with reversed polarity formed when the magnetic field was reversed; conversely, volcanic rock with normal polarity formed when the field had a polarity similar to the present geomagnetic field. The determination of magnetic polarity of specific rock units provides the basis for the stratigraphic correlation of rocks suitable for paleomagnetic analysis.

Outcrops of the middle Yakima Basalt in Arlington, Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek were sampled for paleomagnetic determinations. The sampled sites are shown in Figure 1 (p. 170-171).

Field and Laboratory Techniques

A total of 44 cores were taken from the 11 sites for paleomagnetic study. The sampling technique consisted of drilling a core, 1 inch in diameter and from 2 to 5 inches long, with a portable water-cooled diamond coring drill. The samples were oriented by means of a brass mark of known geographic orientation along the length of the core before the sample was broken free from the host rock. The accuracy of the field orienting method is estimated to be within 3 degrees.

For laboratory measurements, each core was cut into 1-inch cylinders. The paleomagnetic measurements were made on a 5 cps (cycles per second) fluxgate magnetometer of the type described by Foster (1966), and the data were reduced by digital computer. The direction measurements are reproducible to ± 2.0 degrees (standard deviation). The apparatus used for demagnetization experiments is similar to that described by Doell and Cox (1963). It consists of a four-axis tumbler with current in the coils controlled by a variable transformer. Four specimens were subjected to progressive step demagnetization experiments to determine the

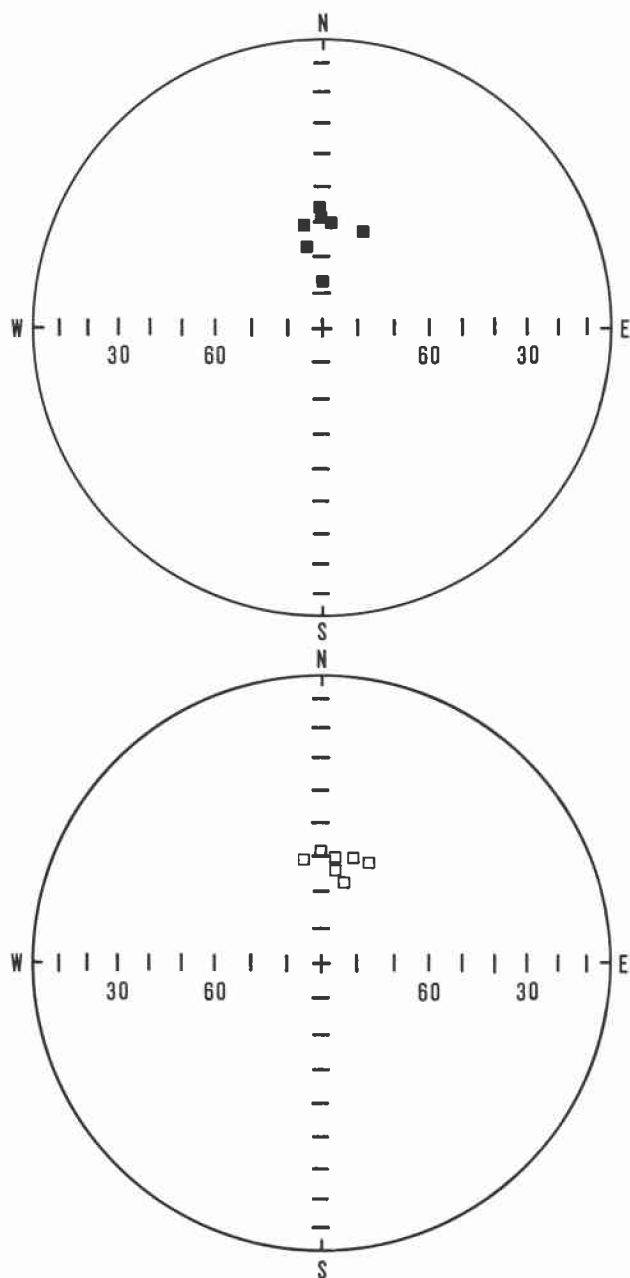
optimum field and thereby remove secondary components of magnetization. The remaining samples were all demagnetized at this field value (200 oersteds) to provide more accurate results.

Measurement Statistics

When several specimens from a given lava flow are sampled and measured, the resulting directions of magnetization are never exactly parallel. Various sources of uncertainty and/or error exist to yield a scatter or dispersion of the measured directions. A basic source of angular deviation arises from the statistical expectation of the magnetization of a finite number of randomly orientated magnetic domains that are not magnetized parallel to the existing Earth's magnetic field during cooling. The magnitude of this effect depends upon the specific properties of a given lava flow. Determining this component of magnetization is difficult and involved; however, the numerous measurements by various investigators provide an approximate average value for "Tertiary lava flows" of from 2 to 4.5 degrees.

Thus, even if there were no other uncertainties, a plot of the measured magnetic direction for a given lava flow would show a scatter of about 5 degrees in arc length. Other sources of scatter include variations in the direction of the local magnetic field, experimental errors in orienting samples and obtaining magnetometer measurement, and small random rotations of blocks of lava after cooling. Previous work has shown that the expected sum of all sources of uncertainty for a typical Tertiary lava flow will yield a scatter of direction of about 10 to 15 degrees (Doell and Cox, 1963). Since the source of the scatter is essentially a statistical sum of random variations, appropriate evaluation statistics can be devised and applied to the data.

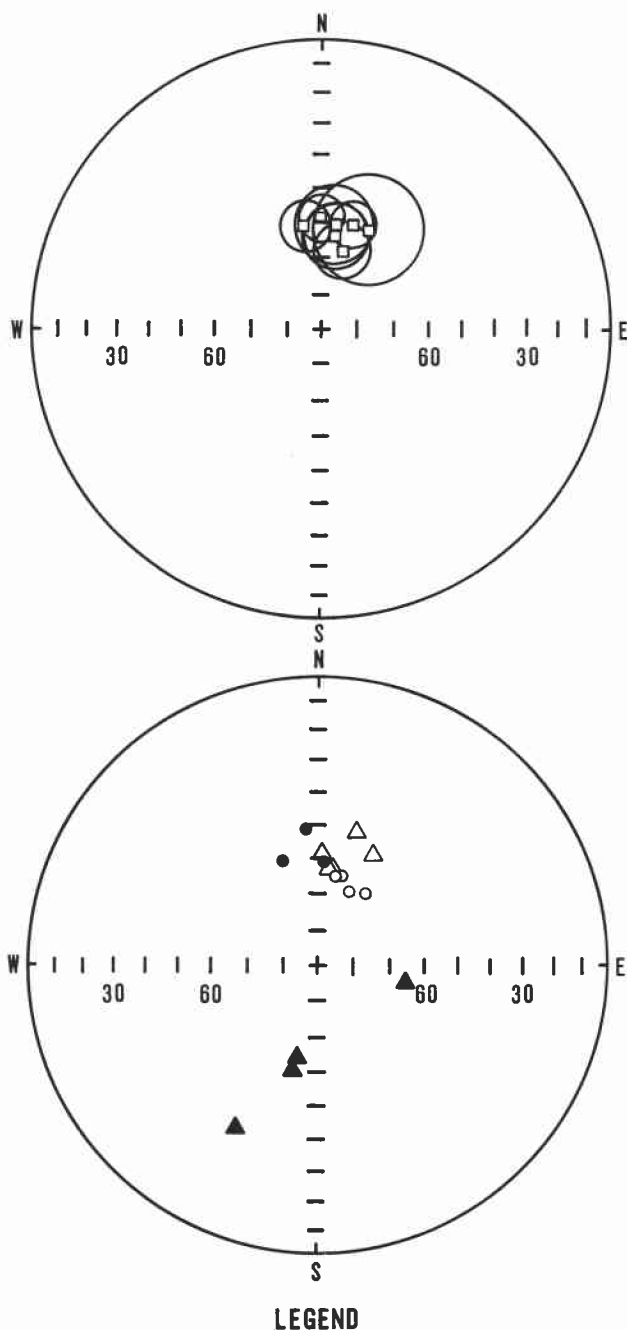
The model used in analyzing paleomagnetic data is one of magnetic field directions (inclination and declination) randomly distributed about a fixed mean direction. The basic statistics in use were developed by Fisher (1953). Using Fisher's statistics, each magnetic direction is given unit weight representing it as a unit vector. The best estimate of the mean direction is given by the vector sum of the individual measurements. In addition, a precision parameter or confidence limit can be determined by using the appropriate function of probability distribution as developed by Fisher (1953). The standard 95 percent confidence circles have been calculated for mean direction, obtained from multiple samples of the same site or flow unit. Thus, 95 percent confidence level means there is one chance in twenty that the true mean direction lies outside the circle of confidence. If circles of confidence for different sites overlap, the implication is that individual sites are statistically indistinct at the 95 percent confidence level: that is, the sites represent essentially the same direction of geomagnetic field.



EQUAL AREA PROJECTION PLOT

- MEAN DIRECTION BEFORE DEMAGNETIZATION
- MEAN DIRECTION AFTER DEMAGNETIZATION

Figure 2. Mean paleomagnetic directions - Juniper Canyon site.



- LEGEND**
- | | |
|-----------------------|--------------------------|
| □ JUNIPER CANYON SITE | ● BUTTER CREEK SITE |
| ▲ ARLINGTON SITE | ○ ELLA BUTTE SITE |
| △ WILLOW CREEK SITE | ○ 95% CONFIDENCE CIRCLES |

Figure 3. Paleomagnetic directions - all sites.

TABLE 1

PARAMETERS OF PALEOMAGNETIC VECTORS
(After Demagnetization at 200 oe)

	Inclination (Degrees)	Declination (Degrees-Azimuth)	Intensity (emu/cm ³)	Paleomagnetic polarity
Arlington Site (1 locality, 4 samples)	-38.0 to -65.9	102.1 to 207.9	1.48 x 10 ⁻² to 9.93 x 10 ⁻⁴	Reversed
Willow Creek Site (4 localities, 5 samples)	+51.3 to +64.5	359.6 to 026.4	1.03 x 10 ⁻² to 6.83 x 10 ⁻³	Normal
Elia Butte Site (2 localities, 4 samples)	+64.7 to +68.2	010.3 to 033.7	2.63 x 10 ⁻³ to 6.41 x 10 ⁻³	Normal
Juniper Canyon Site (3 localities, 28 samples) (90 percent confidence limit 6.0 to 17.5 degrees)	+59.1 to +67.9	349.6 to 017.2	1.48 x 10 ⁻³ to 4.83 x 10 ⁻³	Normal

* Electromagnetic units

Results of Paleomagnetic Determinations

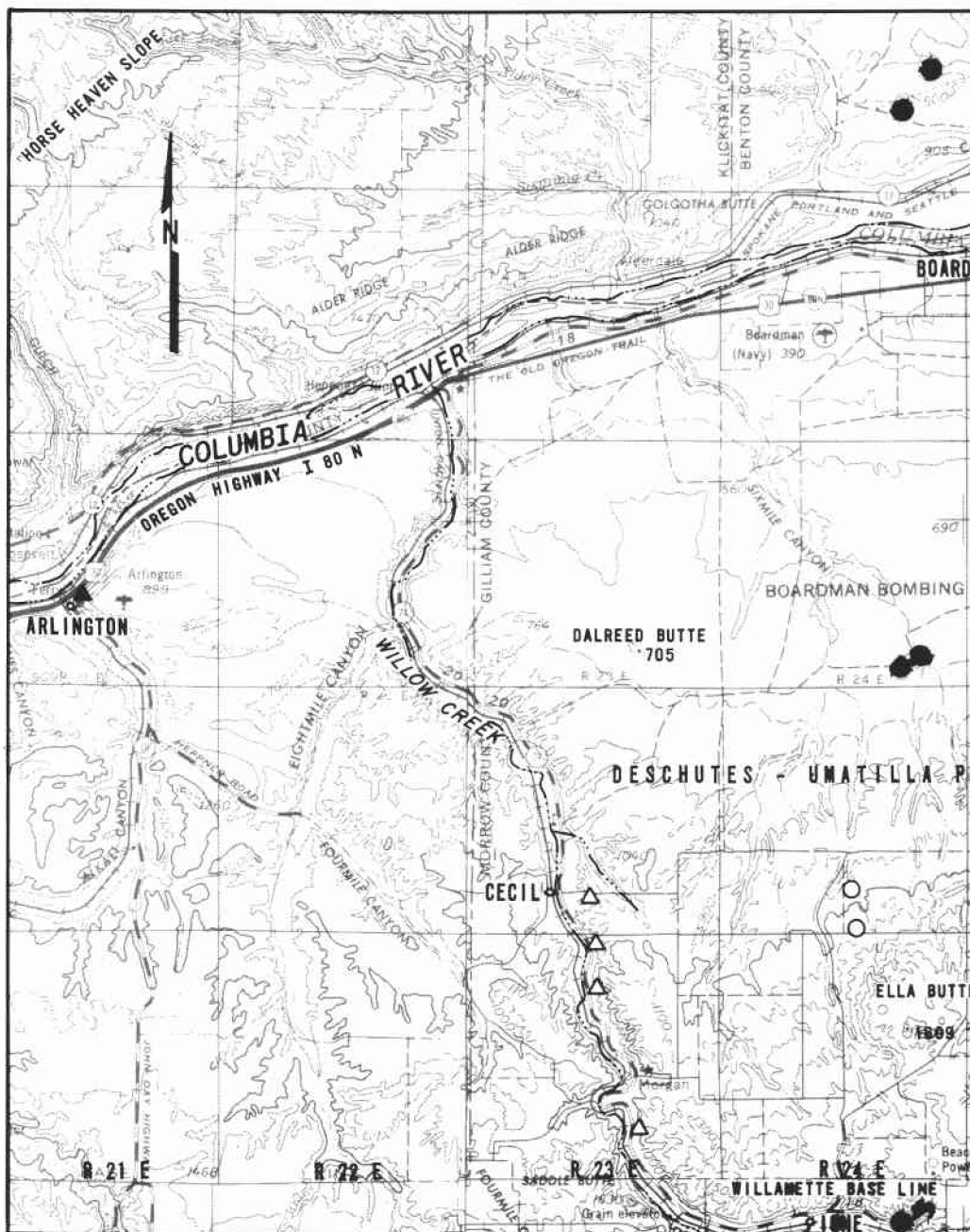
The results are summarized in Figures 2 and 3 and in Table 1. All plots are Schmidt equal-area stereographic projections. Solid triangle symbols indicate reversed polarity directions which penetrate the upper hemisphere; the other symbols are normal polarity directions on the lower hemisphere.

The directions of original remanent magnetization for the various sites sampled display some scatter. The remanent magnetic vector plot in Figure 2 shows the directions of individual samples from Juniper Canyon sites before and after demagnetization at 200 oersteds. The magnitude of the angular dispersion of the directions is typical of many Tertiary lava flows (Heinrichs, 1967). Figure 2 indicates that a small secondary component of magnetization, probably a viscous magnetization, was removed by the demagnetization process. The radius of the 95 percent confidence circle for one of the Juniper Canyon sites was 15.9 degrees before demagnetization and 7.8 degrees after demagnetization, showing the improvement in the quality of the data after "magnetic cleaning" by demagnetization at 200 oersteds. Although the mean direction of magnetization did not change significantly, demagnetization significantly improved the precision of the data.

The mean directions of magnetization of each site, calculated from the vector sum of all individual demagnetized samples, are shown in Figure 3. The data on the original magnetization is of good quality, and no major changes in direction were found after demagnetization. Some secondary components of magnetization were removed by the processing, however, as the tighter grouping indicates. The primary purpose of the top figure, showing circles of 95 percent confidence limit, is to indicate the quality of the basic data. The tight grouping of paleomagnetic directions, together with typical confidence intervals, indicates that Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek sites represent a single direction of the Earth's magnetic field. Samples from these sites have normal polarity. In contrast, samples from Arlington site have reversed polarity. The direction of magnetization for one of the Arlington samples is unreliable, but the polarity is good. This sample exhibited a normal polarity before demagnetization and apparently contained a large secondary component of magnetization that was not completely removed by the demagnetization procedure.

Stratigraphic Correlation of Flows

If two volcanic units have parallel magnetizations, it does not necessarily follow that they cooled at the same time. This is because each possible direction of the Earth's field has recurred more than once in the past. Thus, parallel directions of magnetization are a necessary but not a sufficient condition for establishing that two bodies of volcanic rock cooled simultaneously. The stratigraphic sequence and paleomagnetic polarities of Yakima Basalt are shown in Figure 4. Regional geologic studies



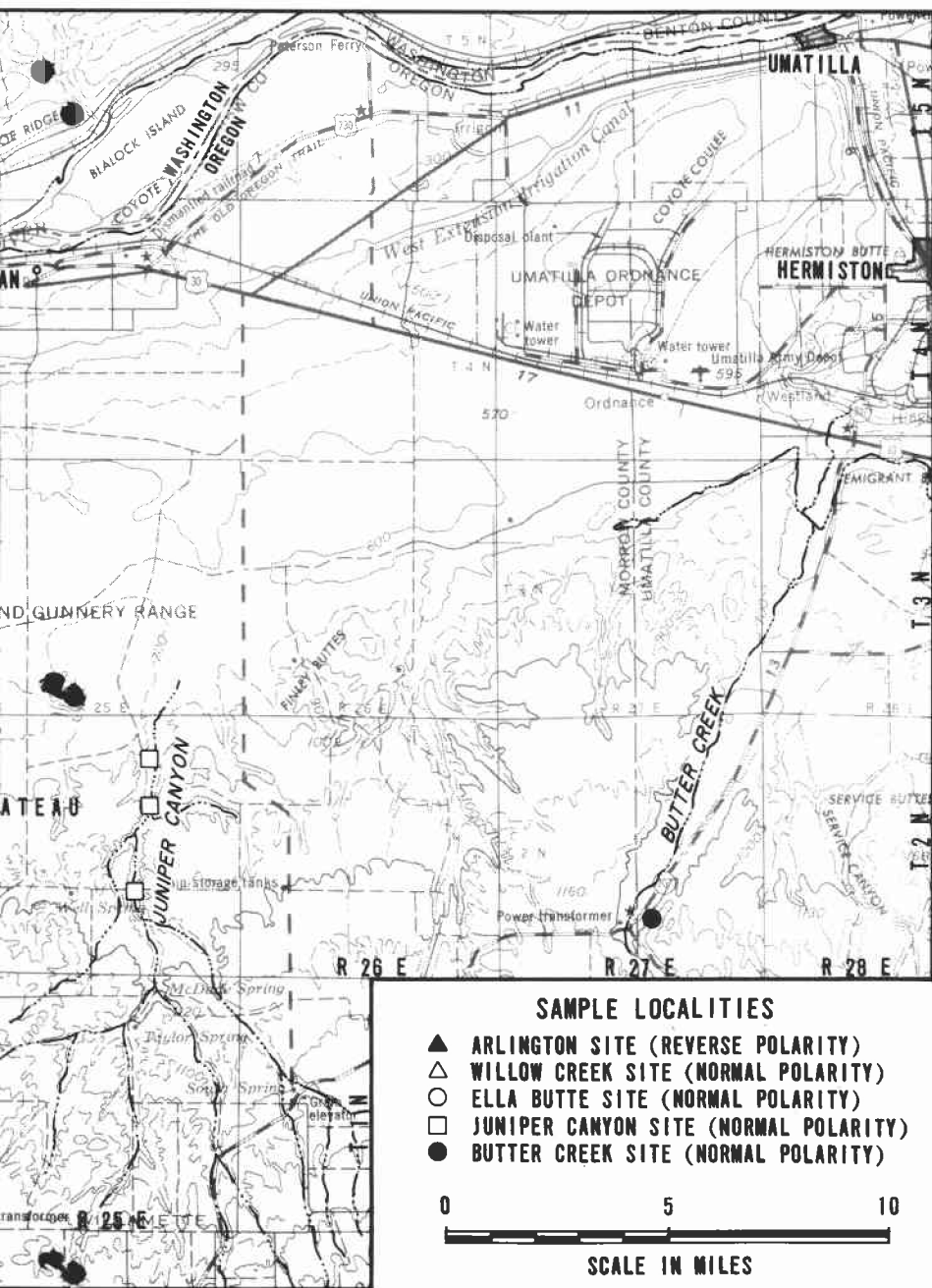
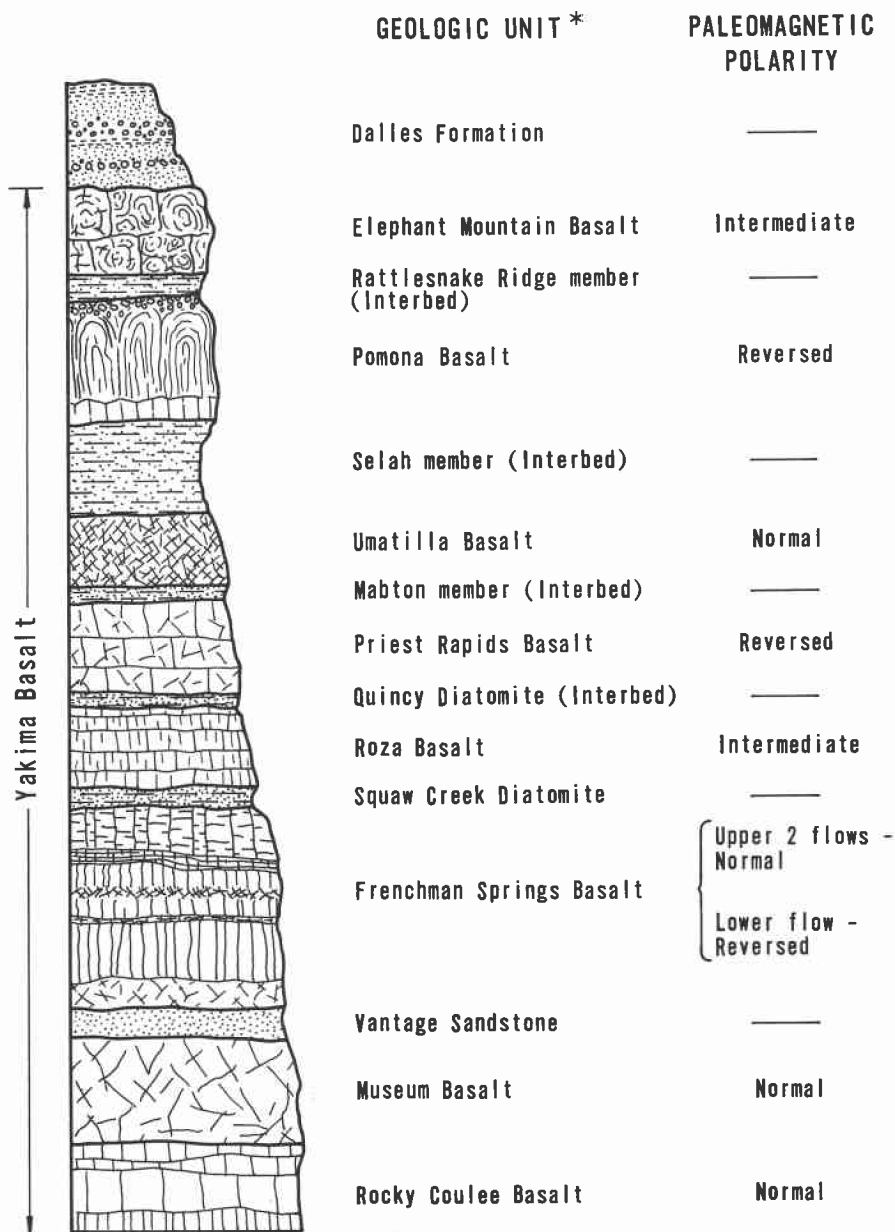


Figure 1. Locations of paleomagnetic samples sites.



* UNITS ARE IN ORDER OF INCREASING AGE. POLARITIES FOR INTERBEDS NOT DETERMINED.

Figure 4. Stratigraphic sequence and paleomagnetic polarities of Yakima Basalt in Oregon (Rietman, 1966; Kienle, 1971; Shannon and Wilson, 1975).

(Shannon and Wilson, 1972, 1975) indicate that the basalt flows sampled at the Arlington, Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek sites are pre-Selah member flows. The reversed polarity flows at Arlington directly underlie the Selah member, so that these flows are correlative to the Priest Rapids Basalt, whereas the normal polarity flows at Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek are correlative to the Frenchman Springs Basalt, which is overlain in this area by either the Dalles Formation or loess, rather than by younger flows of Yakima Basalt. This relationship indicates that each successively older flow of Yakima Basalt in the Deschutes-Umatilla Plateau is more extensive southward.

Acknowledgments

The work in this paper was a part of site geologic studies for Portland General Electric Company's Boardman Nuclear Project, Carty West Site, Morrow County, Oregon. Robert J. Deacon and Clive F. Kienle, Jr. reviewed the manuscript, and Margaret C. Lewis drafted the drawings.

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- _____, 1975, Supplemental report no. 1, Geotechnical investigation for central plant facilities, Carty west site, Boardman nuclear project, Morrow County, Oregon.

* * * * *

MINING ASSOCIATION CONVENTION SLATED

More than 1,000 Northwest Mining Association members from Oregon, Idaho, Montana, Washington, Alaska, and British Columbia are expected to attend the Association's 82nd Annual Convention early next month.

The meetings will be held December 3 and 4 at the Davenport Hotel in Spokane. Association president Henry T. Eyrich has announced the theme: "Gold, Silver, and Platinum in the Northwest."

Dr. John C. Balla, program chairman, explained that this is to be a technical convention for the industry. Convention chairman Robert G. Garwood said a pre-convention short course on Mineral Industry Costs will be held from November 30 to December 2.

* * * * *

WE GOOFED!

In our haste to get out the October issue of The ORE BIN we inadvertently transposed Figures 3 and 4 in the article, "The Deschutes Valley Earthquake of April 12, 1976," by members of the Geophysics Group at Oregon State University. The stereographic projection plot is Figure 4; the map showing locations of epicenters of the various shocks should be Figure 3.

* * * * *

HALBOUTY TO DRILL OIL TEST

The well-known Houston consultant, Michel Halbouty, applied for an oil and gas drilling permit early in October. Halbouty proposes to drill an 8,500-foot exploratory hole approximately 8 miles west of Burns in Harney County. Location applied for is in the SE-NE sec. 10, T. 23 S., R. 29 E. The wildcat will be drilled as a "farm-out" of Standard Oil Company leases. Halbouty drilled two other deep wildcats this summer, one in northern Nevada and the other near Boise, Idaho.

* * * * *

ATLAS OF OREGON PUBLISHED

One of the most useful books to come along for many years is the Atlas of Oregon, published by University of Oregon Books and edited by William G. Loy. The Atlas encompasses a wide variety of subjects under the main headings of Human Geography, Economic Systems, Natural Environment, and Facts, Figures, and Place Names. The book is the work of many and has borrowed heavily from other sources. Due to this broad-based team effort the presentation varies somewhat from page to page, but the over-all level of competence is high. Some of the tables, charts, graphs, and maps are a bit difficult to comprehend immediately; but with careful attention the reader can find information in abundance.

One of the most interesting sections of the Atlas deals with the early period of land acquisition, either through donation land claims of 640 acres per couple in the mid-1850's or by means of wagon road and railroad grants in the 1860's and 70's. The effects of these land transfers is still felt in the odd-shaped parcels of land running back at right angles from the stream banks, in contrast to the neatly ordered squares of one mile each laid out by later surveyors.

As with most books of this kind, the pages are filled with hundreds of maps covering nearly every segment of the State's makeup. Oregon's specialized economic base is revealed quite clearly in a section which shows that only 9 percent of the State is cropland, but larger areas are forest and even larger expanses are rangeland. Another chart shows the State's heavy dependence on imports of energy in the forms of oil and gas.

The Atlas of Oregon sells for \$29.95. It is available at bookstores throughout Oregon and can be ordered for the price plus \$1.50 postage from University of Oregon Press, Eugene, Oregon 97403.

R. S. Mason

* * * * *

BUREAU OF LAND MANAGEMENT GAINS OPERATING CHARTER

Management of 16 million acres of national resource lands in Oregon and Washington will be simplified under a law signed by President Ford last October 22.

The Federal Land Policy and Management Act of 1976 establishes a policy of continued Federal ownership and sets guidelines for administration and management of the 473 million acres and their resources by the Interior Department's Bureau of Land Management.

Some sections of the law also apply to national forest lands administered by the Forest Service of the U.S. Department of Agriculture.

Since creation of the Bureau of Land Management in 1946, successive Presidents have sought a law that would replace the more than 3,000 public land laws applying to the public domain, some dating back to the post-Revolutionary War period. Many of these antiquated laws have been replaced by the new act.

Secretary of the Interior Thomas S. Kleppe called the new law "a monumental step leading to a new era in management of the public lands and their resources."

Kleppe said, "It has often been necessary to administer the affairs of these lands through executive order or by departmental regulations. Although this law is not everything we had hoped for, it is workable and represents a major step forward in public resource management for the lasting benefit of the American people."

Also commenting on the new law, Bureau of Land Management Director Curt Berklund said, "We realize the immense responsibility this law gives us, along with the tools to carry out this mandate. This legislation has been sorely needed, but we want to move very deliberately with the fullest public involvement in putting it in practice."

"We are taking a close look at this new mandate to determine which sections can be implemented immediately, as well as those that will require extensive regulation development. Full implementation will be an involved process," Berklund emphasized.

BLM's Oregon State Director Murl W. Storms said, "The new act will certainly permit more efficient management of national resource lands in Oregon and Washington. It is a mandate for multiple use, sustained yield resource management. It also streamlines procedures for land exchanges, provides for designation of wilderness areas, and permits acquisition of lands needed for outdoor recreation."

"The legislation finally repeals the homestead laws, which prompted thousands of public inquiries despite the fact that virtually no land has been available for homesteading in Oregon and Washington for several decades."

Storms added, "The section allowing us to use helicopters in herding wild horses to gather the excess over those the range can support will help us, also."

The new law is lengthy and comprehensive. Some of its provisions are;

- Gives broad management authority under the principles of multiple use and sustained yield.

- Authorizes the inventory and identification of the public lands and provides authority for marking and mapping these lands.

- Calls for comprehensive land use planning.

- Authorizes the use of Land & Water Conservation Fund money to acquire lands for proper management of public recreation lands.

- Authorizes cash payments to equalize values when public lands are exchanged for private lands, provided the cash payment does not exceed 25 percent of the total value of the Federal land involved.

- Provides for enforcement of public land laws and regulations by Federal personnel or by appropriate local officials who have entered into contracts with the Secretary of the Interior.

- Provides for distribution of funds collected for grazing fees with 50 percent of all money collected earmarked for range improvements.

- Authorizes loans to state and local governments against their share of anticipated mineral revenues to relieve impacts of mineral development.

- Requires persons holding mining claims under the general mining law of 1872 to record those claims with the Bureau of Land Management.

- Authorizes the Bureau of Land Management to carry out wilderness studies on the national resource lands with such studies to be completed within 15 years.

* * * * *

REPUBLIC GEOTHERMAL TO BEGIN OREGON DRILLING

Republic Geothermal, Inc., Santa Fe Springs, California applied in October to drill two deep geothermal wells near Vale in Harney County, eastern Oregon. The test holes will be put down on Magma Energy leases under a "farm-out" arrangement. Republic was successful bidder on a 1,350-acre Federal tract adjacent to the Magma Energy private lands leases in June 1974. Data on the two applications are:

<u>Permit number</u>	<u>Well name</u>	<u>Location</u>	<u>Date</u>	<u>Proposed depth</u>
11	Butler V-1	NW-SE sec 28 T18 S, R 45 E	Sept. 20, 1976	1,500'
12	Butler 1/55-28	NW-SE sec 28 T18 S, R 45 E	Sept. 20, 1976	8,000'

* * * * *

DOGAMI TO DRILL GEOTHERMAL WELL

The Department proposed the drilling of a 1000-foot geothermal test hole this fall. The site is approximately 14 miles southwest of Heppner, near Black Mountain, in Morrow County. The work will be done in the Umatilla National Forest. Purpose of the project is to obtain temperature gradient data in pre-Tertiary intrusive rock.

This drilling is a continuation of a cooperative research study with the U.S. Geological Survey to explore the geothermal potential of the State. The project has included the drilling of more than 40 gradient holes to depths ranging between 200 and 500 feet. Exploration focused along the Brothers fault zone, the Vale thermal area, and along the west side of the Cascade Mountains.

Permit number	Well name	Location	Date	Proposed depth
10	Black Mt. test hole	NE-SE sec 21 T 4 S, R 28 E	Oct. 1976	1,000'

* * * * *

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