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THE SALEM METEORITE

Also in this issue:

BLUE MOUNTAINS FIELD TRIP GUIDE—PART I

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COVER PHOTO

The five recovered fragments of the Salem meteorite of May 13, 1981, Oregon's first meteorite to be recovered immediately after it fell. Details of the event are described in article beginning on next page.

OIL AND GAS NEWS

Mist Gas Field

In April, Reichhold Energy Corporation, operator at Mist Gas Field, put two new wells on line. The wells, Paul 34-32 in sec. 32, T. 7 N., R. 5 W., and Columbia County 13-34 in sec. 34, T. 7 N., R. 5 W., were drilled and completed in November and December of last year. Initial tested production was 1,400 Mcf per day and 473 Mcf per day, respectively. The wells were shut in for four months, until a gathering line was completed by Northwest Natural Gas Company.

Reichhold Energy has started its Oregon drilling program for the year. Columbia County 14-33 was drilled and abandoned in sec. 33, T. 7 N., R. 5 W., in April. Total depth was 3,105 ft. Their next drilling will also be in the northwest portion of Mist Gas Field.

Address changes for Mist partners:

Reichhold Energy and Northwest Natural Gas Company, two of the partners at the Mist Gas Field, have both moved to new offices. Effective May 1, 1983, new locations and phones are as follows: Reichhold Energy Corporation, 1410 SW Marlow Ave., Portland, OR 97225, (503) 297-7633; Northwest Natural Gas Company, One Pacific Square, 220 NW Second Ave., Portland, OR 97209, (503) 226-4211.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
235	Diamond Shamrock Watzek Trust 23-4 007-00015	SW¼ sec. 4 T. 6 N., R. 6 W. Clatsop County	Location; 6,000.
236	Diamond Shamrock Watzek Trust 31-4 007-00016	NE¼ sec. 4 T. 6 N., R. 6 W. Clatsop County	Location; 6,000.
237	Reichhold Energy Columbia County 23-22 009-00116	SW¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Application; 5,000.

□

USGS offers new air photos

The U.S. Geological Survey's National Cartographic Information Center—West (NCIC-W) offers photographic coverage of most of Oregon in the new National High Altitude Photography Program. Available are black-and-white and color-infrared photos flown in a north-south direction. There are three black-and-white and five color-infrared exposures per 7½-minute quadrangle, each covering about 130 and 68 square miles, respectively. Paper prints, film positives, and film negatives can be purchased at prices beginning at $5 (9×9 b/w print).

A complete index and detailed information on availability and quality of individual photos can be consulted at the Oregon State Library, State Library Building, Salem, OR 97310. A partial collection is held by the University of Oregon Library in Eugene. □

CONTENTS

The Salem meteorite

by Richard N. Pugh, Science Teacher, Cleveland High School, Portland, Oregon 97202

The fifth meteorite to be found in Oregon fell on a house in Salem on May 13, 1981. The time of the fall was 1:05 a.m., Pacific daylight time (07:05 Greenwich mean time). The location of the fall was lat. 44°58′45″ N., long. 123°58′10″ W. (NW¼NW¼ sec. 8, T. 7 S., R. 2 W., Willamette Meridian, Marion County).

The meteorite struck the house of Marion County Deputy Sheriff James P. Price, who was sitting on the curb in front of his home talking to Deputy Sheriff Vincent Wan, who was in his patrol car. Both officers heard a peculiar fast "fluttering" noise, an impact of something hitting the house, and then the sound of small rocks falling near them. Price examined the area by flashlight and within ten minutes found the first and largest piece of the meteorite in front of his driveway. This specimen, which was warm to the touch, had landed within 10 ft of the officers. Because of his training as a physics major at Linfield College, Price recognized the broken specimen as a meteorite.

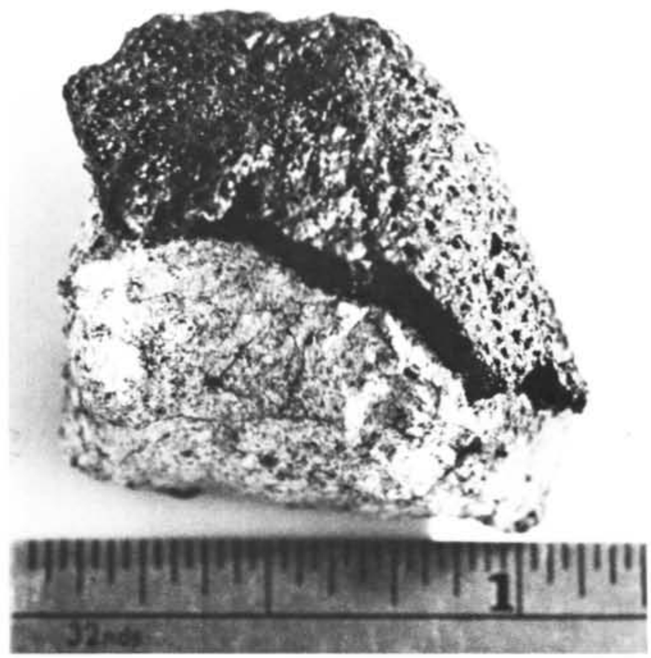
The next morning four more pieces of the meteorite were recovered—one on the back side of the garage roof, one in the gutter on the front of the garage, one on the driveway leading to the garage, and one in the street opposite the driveway where the first specimen had been found earlier that morning. The second piece found in the street had been run over by an automobile.

In all, five major pieces and a few very small fragments were recovered. The weights of the five pieces are 22.23 g, 17.65 g, 9.90 g, 8.05 g, and 3.45 g, a total of 61.28 g—just over 2 oz.

Three of the pieces fit together to form about half of the original meteorite. The two remaining pieces fit together but do not fit the first three, indicating that about a third of the meteorite was not recovered.

The original meteorite was in the shape of a flat oval about 6 cm long, 5 cm wide, and about 2.5 cm thick. The fusion crust formed on the leading face of the meteorite as it fell is smooth and about 1 mm thick, while the fusion crust that formed on the trailing side of the meteorite is pitted and measures up to 2.8 mm in thickness. No regmaglypts (indentations resembling thumbprints) were found on the meteorite fragments.

The meteorite interior is concrete gray and shows almost no



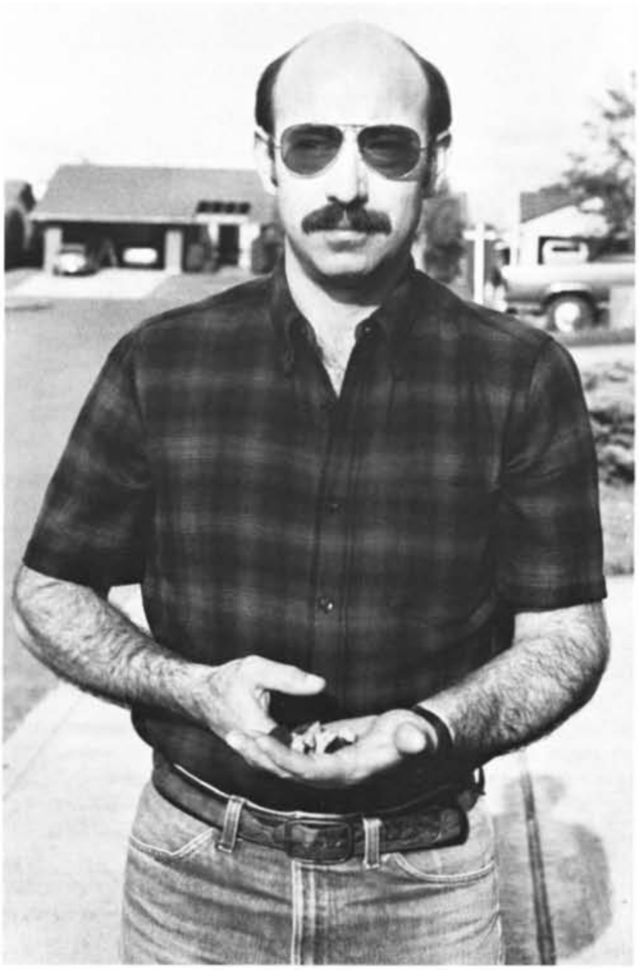
Largest fragment of Salem meteorite, showing fusion crust almost 3 mm thick. This fragment was warm to the touch when it was first picked up.

Five recovered fragments of the Salem meteorite. Note fusion crust.

The James P. Price home, which was hit by the Salem meteorite on May 13, 1981. The meteorite hit the second row of shingles (arrow) from the top of the garage roof directly above the post between the garage doors. The first fragment was found on the street in front of the driveway, another was found in the gutter of the roof, a third was found on the back side of the roof, another in the driveway, and another in the street.

metal. It is only slightly attracted to a magnet.

Price discovered that the meteorite had struck the front center of his garage in the second row of asphalt shingles below the peak of the roof, breaking out a circular piece about 6 cm in diameter in the bottom of one shingle. This indicates that the meteorite came from the southwest at a low angle—barely clearing the peak—before impacting the roof and shattering. Had the meteorite hit the roof at a steeper angle, it probably would have penetrated the roof.

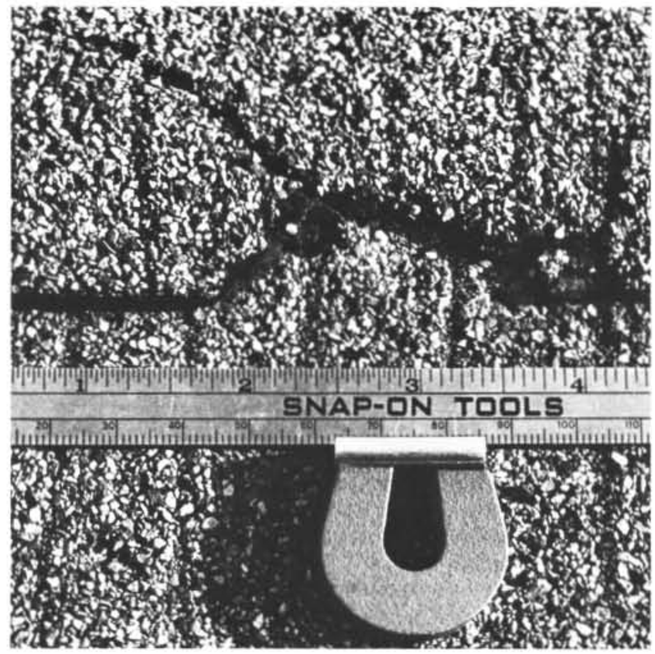


Deputy Sheriff James P. Price holding the Salem meteorite.

No fireball, sonic boom, or electrophonic noises were reported in association with the Salem meteorite fall.

About six weeks after the meteorite fell, Price met Roman Schmitt of the Oregon State University Radiation Center, who suggested that the meteorite be sent to J.C. Evans, Senior Research Scientist, Battelle Pacific Northwest Laboratories in Richland, Washington, for analysis. Using a combination of scanning electron microscopy and energy dispersive X-ray fluorescence, Evans (personal communication, 1982) found the meteorite to be an LL5 chondrite, known also as an amphoterite, a low-iron, low-metal chondrite. The number indicates the petrologic type, with "5" meaning blurred chondrule-matrix boundaries and coarsening of devitrified glass (Todd, 1981). Amphoterites are the rarest type of ordinary chondrites, comprising only 7 percent of all meteorites (Wasson, 1974).

The Salem meteorite is the first meteorite known to fall and then be recovered in Oregon. It also has the distinction of being the first stony meteorite recovered in the state. It is still in the possession of James Price, whose house it hit.



Notch in asphalt shingle where meteorite struck roof.

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Sears, D.W., 1978, Nature and origin of meteorites: New York, Oxford University Press, Monographs on Astronomical Subjects, v. 5, p. 57.

Todd, R.T., 1981, Meteorites: A petrologic-chemical synthesis: New York, Cambridge University Press, p. 23-25.

Wasson, J.T., 1974, Meteorites: Classification and properties: New York, Springer Verlag, p. 20. □

Granite geologic map published

A new geologic map of the Granite quadrangle in Grant County, eastern Oregon, has been released by the Oregon Department of Geology and Mineral Industries (DOGAMI).

Geology and Gold Deposits Map of the Granite Quadrangle, Grant County, Oregon, by H.C. Brooks, M.L. Ferns, and E.D. Mullen, is a multicolor geologic map at a scale of 1:24,000. It shows 17 different bedrock and surficial geologic units, delineates the geologic structure, and locates quartz veins, mines, prospects, and rock sample sites. In addition, the map includes two geologic cross sections, a table listing detailed information on 77 identified mines and prospects, a table showing chemical analyses of 16 rock samples, and a brief discussion of the area's mineral deposits.

Published as Map GMS-25 in DOGAMI's Geological Map Series, the map represents another step in the Department's continuing efforts toward comprehensive geologic coverage of the traditional eastern Oregon gold province. Mainly in cooperation with and supported by funding from the U.S. Forest Service, DOGAMI has so far published geologic maps of the Mineral (GMS-12), Huntington/Olds Ferry (GMS-13), Bourne (GMS-19), Mount Ireland (GMS-22), Bullrun Rock (OFR 0-79-6), and Rastus Mountain (OFR 0-79-7) quadrangles. The mapping will continue with soon-to-be-published maps of the Greenhorn, Bates NE, Bates NW, and Bates SW quadrangles. Together, these maps will cover the old mining districts of Cable Cove, Cracker Creek, Granite, Greenhorn, and Quartzburg and parts of the Rock Creek, Sumpter, Susanville, and Unity mining districts.

The published maps are available at the DOGAMI offices in Portland and Baker. For prices, see the publication list at the end of this issue. Mailed orders under $50 require prepayment. □

Paleozoic and Triassic terranes of the Blue Mountains, northeast Oregon: Discussion and field trip guide*

Part I. A new consideration of old problems

by Ellen D. Mullen, Department of Geology, University of Arkansas, Fayetteville, Arkansas 72701, and Daniel Sarewitz, Department of Geology, Cornell University, Ithaca, New York 14853

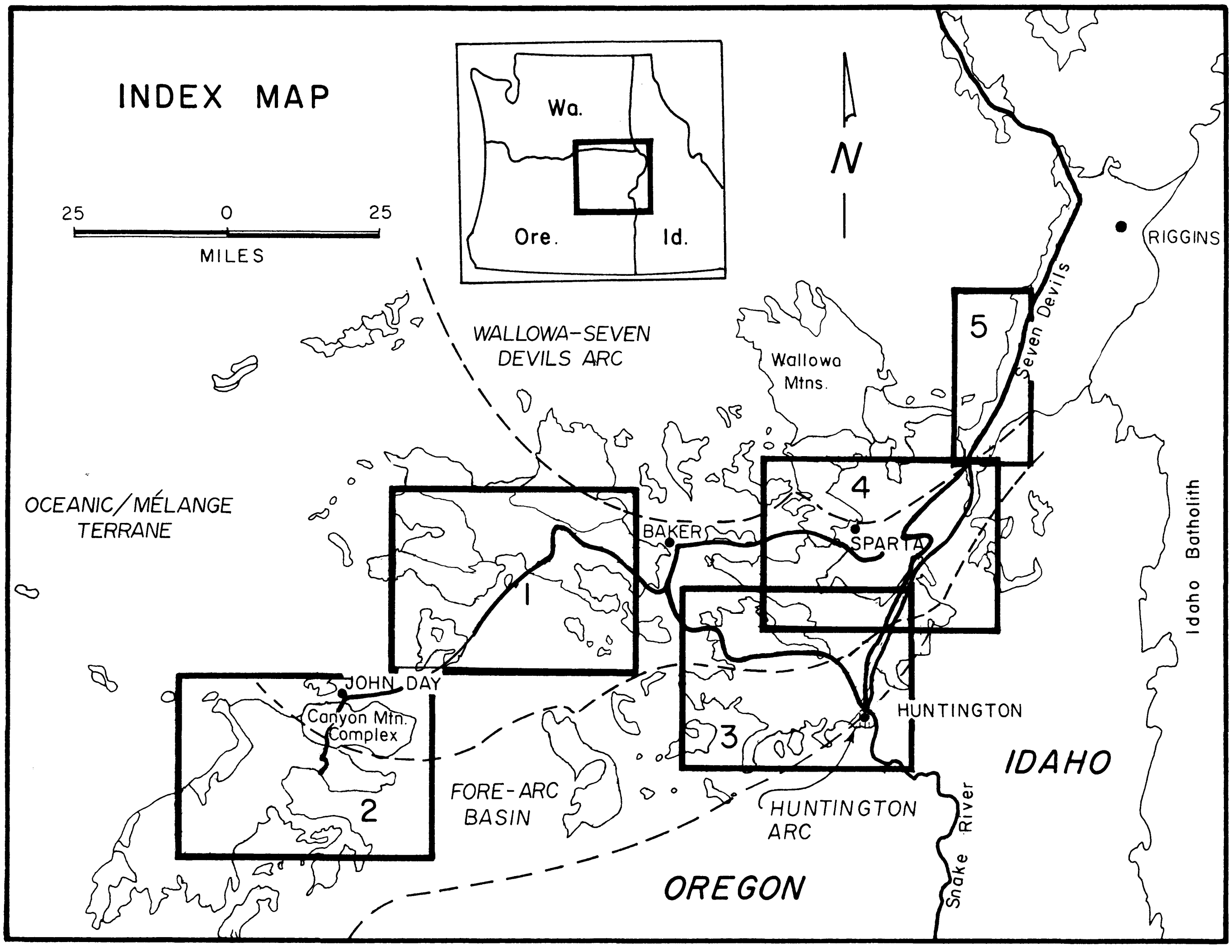
INTRODUCTION

The Blue Mountains of northeast Oregon and western Idaho contain an assemblage of late Paleozoic and Triassic to Jurassic rocks which may represent fragmented oceanic and island-arc crust. These diverse units were probably accreted to the North American Plate during the Late Triassic and Jurassic. Although their origins are not completely understood, these metavolcanic, metasedimentary, and plutonic rocks can be generally described in terms of plate-tectonic environments. (See Brooks, 1979, for a detailed regional discussion.)

Four genetic terranes have been recognized by recent workers (Dickinson and Thayer, 1978; Brooks and Vallier, 1978; Dickinson, 1979). They are (1) the dismembered oceanic crust terrane of Brooks and Vallier (1978) or central mélange terrane of Dickinson and Thayer (1978)—called the oceanic/mélange terrane in the following discussion, (2) the Wallowa-Seven Devils arc, (3) the Huntington arc, and (4) the Triassic to Jurassic forearc terranes. These terranes are shown on the index map.

OCEANIC/MÉLANGE TERRANE

The oceanic/mélange terrane is centrally located and incorporates metasediments and metaigneous rocks mostly of Permian and Triassic age. It extends from western Idaho near the Snake River west to Dayville, where it disappears beneath Tertiary volcanics.



Index map showing terranes of the Blue Mountains as discussed in this paper. Numbered rectangles delineate field trip maps of Part II, to be published in next month's issue of Oregon Geology.

* *This is a two-part paper of which only Part I is printed here. Part II, road log and commentary, will be published in the July issue of* Oregon Geology.

Limited exposures of serpentinite-matrix mélange and pre-Tertiary rocks which may be related occur near Antone and Mitchell. Rare occurrences of limestones southwest of Grizzly Butte near Madras and in Smith Rocks suggest that the terrane may extend far westward toward the Cascades beneath Tertiary cover.

This oceanic/mélange terrane is dominated by fine argillite and chert of the Elkhorn Ridge Argillite which is locally contorted and sheared. Mafic greenstones are interbedded with these sedimentary rocks and form less than 20 percent of the outcrops. Coarser metasediments, including graywacke and fine conglomerates, are included in the Elkhorn Ridge Argillite and are often associated with felsic volcanics. Limestone lenses which vary from less than 3 ft to several hundred feet in length and contain fusulinids and/or conodonts are commonly enclosed within cherts. They seem to retain some stratigraphic coherence with enclosing sediments in the Greenhorn Mountains (Mullen, 1978), on Elkhorn Ridge (Coward, 1982), and near Coyote Butte in south-central Oregon (Wardlaw and others, 1982). Fossils from these limestones were the basis for assigning the Elkhorn Ridge Argillite a Pennsylvanian to Early Triassic age. However, some limestone lenses may be substantially older than the enclosing cherts.

Two fusulinid faunas occur in the limestone blocks—one is Tethyan (Asian), the other is North American. The Tethyan faunas are considered exotic and native to the western Pacific-Tethys region. They have been considered evidence for the origin of these limestones in an area remote from western North America. No mixed Tethyan and North American faunas are known, suggesting that if long-distance transport of limestone with Tethyan fossils did not occur, then at least the fusulinid assemblages developed in effectively separated depositional environments (Nestell, 1980). No apparent difference in conodont assemblages has been recognized between "Tethyan" and "North American" limestones in rare locations where both conodonts and fusulinids occur in the same limestones.

Radiolarians in the Elkhorn Ridge Argillite cherts are pervasively recrystallized. They have yielded Triassic to Early Jurassic dates at two localities: Dog Creek near John Day (Vallier and others, 1977) and Elkhorn Ridge near Sumpter (Coward, 1982).

The Burnt River Schist occurs along the Snake River and westward to Bridgeport and is included in the oceanic terrane. It contains sheared greenstones but is mostly a highly silicic phyllite which is gradational in some locations to cherts and argillites similar to Elkhorn Ridge Argillite. Dates for Burnt River Schist are tenuous. It has been considered contemporaneous with the Elkhorn Ridge Argillite because of lithic similarity. Conodonts collected by Mullen from marble pods along the Burnt River are Triassic (Wardlaw, personal communication, 1980). Poorly preserved conodonts collected by Mullen from the Nelson Marble enclosed in Burnt River Schist near Durkee are Triassic and possibly Early Triassic in age (Wardlaw, personal communication, 1980). These ages suggest that the Burnt River Schist is contemporaneous with or slightly younger than the Elkhorn Ridge Argillite, and the overall record in the limestones and cherts suggests that the oceanic/mélange terrane has a long and possibly continuous depositional history.

Greenstones associated with both the Elkhorn Ridge Argillite and Burnt River Schist are predominantly mafic to intermediate in composition. They are not pervasively spilitized, and many contain relict pyroxene and plagioclase. Pyroxenes have high Ca content and high Al_2O_3/SiO_2 and low TiO_2/SiO_2 ratios, which suggests association with an island arc (Mullen, 1982b). In the Greenhorn Mountains and along the Snake River near Sturgill, pillowed mafic greenstones intercalated with cherts contain relict titanium-rich pyroxene (titanaugite), indicating that the original basalts were alkalic (Mullen, 1979; 1982a). Alkalic basalts are characteristic of seamounts and have also been reported from rift zones and oceanic transform faults. Hence, the greenstones of these two localities may represent accreted seamount volcanics, or they may indicate that extensional tectonics affected the area during Permian or Triassic time.

The leucocratic nature of greenstones, the character of pyroxenes in mafic greenstones, and the detrital nature of sedimentary rocks in the Greenhorn Mountains and elsewhere suggest that the Elkhorn Ridge Argillite and Burnt River Schist may not be only an abyssal assemblage but were in part generated closer to an arc. Coarse Permian sediments previously mapped as Triassic to Jurassic (Brown and Thayer, 1966) occur in the southern Greenhorn Mountains and may extend to the north part of Dixie Butte. These coarse wackes and conglomerates are mixed with cherts and argillites and include interbedded limestones with Early Permian (Wolfcampian to Leonardian) fusulinids and conodonts. The prevalence of large, angular volcanic clasts in these sediments suggests a nearby volcanic source. In the Greenhorn Mountains a boulder conglomerate of very limited extent consists of well-rounded diorite and andesite boulders 2 ft in diameter and may also be derived from an arc. These coarser rocks may represent a tectonically disrupted Permian arc or forearc region (Mullen, 1978). They are not characteristic of pelagic oceanic environments.

Two large, coherent blocks of ultramafic to silicic igneous rocks, the Canyon Mountain Complex and the Sparta complex, have been considered ophiolites (a sequence of rock similar to oceanic crust) and are generally included in the oceanic-mélange terrane. However, both are anomalously silicic for oceanic crust and are probably related to island-arc magmas (Phelps and Avé Lallemant, 1980; Gerlach and others, 1981).

The Canyon Mountain Complex south of John Day is of Permian age (Walker and Mattinson, 1980). It occurs along the southern limit of the oceanic/mélange terrane. The complex includes peridotite (40 percent), layered gabbro (20 percent), and isotropic gabbro (10 percent) which were deformed and altered prior to development of upper-level keratophyre, plagiogranite, diabase, and diorite (30 percent total). Zircon-bearing gabbro of the complex has been dated by U-Pb at 278 m.y. (Walker and Mattinson, 1980); plagiogranites and diorite dated by ^{40}Ar-^{39}Ar are 268 m.y. old (Avé Lallemant and others, 1980). Amphibolite at the western edge of the complex is 258 m.y. old (Avé Lallemant and others, 1980) and is probably related to emplacement. Peridotite of the Canyon Mountain Complex is transitional to mélange on the north and west; Tertiary volcanic rocks and faulting obscure its south and east extensions.

The mineralogy and geochemistry of Canyon Mountain provide conflicting evidence regarding its origin. Major-element chemistry of the Canyon Mountain rocks defines a calc-alkaline trend (Thayer, 1977). However, mineralogical trends of the gabbro and pyroxenites are tholeiitic (Himmelberg and Loney, 1980), and keratophyres and quartz diorites of the complex have a flat, tholeiitic rare-earth-element (REE) pattern (Gerlach and others, 1981) suggestive of ocean-basin or early island-arc rocks. Major-element trends for the leucocratic components suggest the plutonic and volcanic rocks were coeval and from a similar source (Gerlach, 1980). Mineral compositions indicate the harzburgite (peridotite) is refractory material from which gabbros and sheeted dikes were derived (Himmelberg and Loney, 1980). However, field evidence suggests that some gabbros intrude the peridotite, rather than being derived from it. The undeformed keratophyre, plagiogranite, diorite, and diabase were added to the complex after deformation of peridotite and most gabbros. Hence the Canyon Mountain Complex is not a simple, contemporaneous "layer-cake" stack of differentiated magmas.

The Sparta complex near the northern limit of the oceanic/mélange terrane is Triassic, with ages of 218 m.y. according to ^{40}Ar-^{39}Ar (Avé Lallemant and others, 1980) and 219 m.y. based on U-Pb (Walker, 1981). It is more silicic than the Canyon Mountain Complex. Strongly serpentinized ultramafic rocks comprise about

10 percent of the Sparta rocks. Relatively undeformed layered and massive gabbros comprise about half of the complex. They are overlain and intruded by diorite and plagiogranite (Phelps, 1979). Blue-quartz-bearing plutonic plagiogranites grade texturally into hypabyssal and volcanic keratophyre (Brooks, 1979), suggesting simultaneous volcanism and plutonism. The Sparta complex contains rocks with rare-earth element (REE) patterns which indicate a tholeiitic affinity. Increasing light-rare-earth (LREE) enrichment from gabbro through quartz diorite to albite granite and keratophyre suggests a single magma series (Phelps, 1979) that could correlate to the early stages of a Triassic arc.

Much of the oceanic/mélange terrane lacks apparent lithologic coherence and seems to be a truly chaotic mélange. It includes broad zones of serpentinite-matrix mélange, about a mile wide and at least several miles long, generally oriented east-west to northwest-southeast. Clasts within the mélange include all lithologies common to the oceanic terrane plus amphibolites, moderate- to high-pressure schists, and fragments of ophiolite.

The origin and significance of mélanges within the oceanic/mélange terrane are not well understood. Blueschist "knockers" (conspicuous blocks of erosionally resistant rock) near Mitchell dated at 223 m.y. have been linked to a possible Triassic subduction zone (Hotz and others, 1977). Their northeasterly strike is anomalous with regard to the general east-west orientation of most late foliations in the oceanic/mélange terrane.

Other localities of mélange at Mine Ridge, near Hereford, in the Greenhorn Mountains, and near Mount Vernon contain high-pressure schists and amphibolite with minerals characteristic of pressures between 5 and 7 kilobars (Mullen, 1978). These mélanges may represent east-west- or northwest-southeast-trending sutures which bound more competent tectonic slices of arc, forearc, and oceanic terranes (Mullen, 1978, 1980), or they may be discrete, separately generated diapir intrusions. The geometry and relations of mélange localities are difficult to resolve due to extensive Tertiary cover.

WALLOWA-SEVEN DEVILS AND HUNTINGTON ARC TERRANES

A thick (19,000 ft) pile of altered Permian and Triassic volcanic and volcaniclastic rocks is present in the Wallowa Mountains, Snake River Canyon, and Seven Devils Mountains. These rocks constitute the Seven Devils Group and represent the Wallowa-Seven Devils island-arc terrane of Early Permian and Middle to Late Triassic age. Overall, volcaniclastic rocks are more abundant than flow rocks, a feature which is typical of volcanic-arc environments. Flow rocks are generally metamorphosed to lower greenschist facies. They are most commonly intermediate in composition, but metabasalt and silicic volcanic rocks are locally abundant. Trace- and major-element data indicate a calc-alkaline trend for Seven Devils volcanic rocks near Riggins, Idaho (Sarewitz, 1982).

Plutonic rocks which probably represent arc basement occur infrequently in the Seven Devils Group. They include trondjhemite, tonalite, quartz diorite, and gabbro, usually deformed and irregularly distributed within the Snake River Canyon and eastward into Idaho. The ages vary from 256 to 225 m.y., but cluster near 248 m.y. (Walker, 1981). Hence, plutonic remnants of major arc activity in the Seven Devils Group are Triassic.

In the east part of exposures, the Seven Devils Group is unconformably overlain by Middle Triassic platform sediments, including the Hurwal Formation, the equivalent Lucille Formation, and the Martin Bridge Limestone. In the northern Wallowas, limestones are late Carnian to early Norian in age (Nolf, 1966).

Ammonites and brachiopods collected by Mullen (1978) yielded a latest Carnian (Triassic) age for platform limestones in the southeast Wallowas along the Imnaha River. Conodonts found by Sarewitz near the base of the Martin Bridge in western Idaho west of Riggins are early to middle Norian in age.

A belt of deformed greenstones and Triassic plutonic rocks occurs in Hells Canyon near the southern limit of the Wallowa-Seven Devils terrane. This zone, sometimes called the Oxbow-Cuprum shear zone, is about 1,600 ft wide and consists of alternating mylonitic greenstones, keratophyres, and diabases which have undergone multiple flattening deformations (Schmidt, 1980). The dissection and amount of displacement along this zone is uncertain. However, its presence near the southern limits of the Seven Devils Group may be significant.

South of the Seven Devils terrane, along the Snake River near Huntington and eastward to Peck Mountain, Idaho, altered volcanic rocks of the Huntington arc are exposed. These rocks are generally similar in character and age to the Seven Devils Group, although rocks of the Huntington arc are limited to the Upper Triassic. Volcanism in the Seven Devils ended in the late Carnian, whereas Huntington arc volcanic activity continued at least into the middle Norian (Brooks, 1979). Intrusive diorites associated with the Huntington arc have been dated as 210-217 m.y. (Brooks, 1979).

Paleomagnetic data indicate that the Wallowa-Seven Devils and Huntington arcs are part of an exotic block that may have been created far south of its present location (Hillhouse and others, 1982). Jones and others (1977) have correlated the Wallowa-Seven Devils arc with rocks of Wrangellia – an accreted terrane composed largely of Permian and Triassic tholeiitic basalts and cherts overlain by Upper Triassic platform limestones which occur in the Wrangell Range of Alaska, on Vancouver Island, and on the Queen Charlotte Islands, British Columbia. However, the results of paleomagnetic studies are not conclusive. Furthermore, the considerable proportion of intermediate volcaniclastic lithologies and the mature volcanic arc affinity of flow rocks (Sarewitz, 1982) make correlation with the thick tholeiitic basalt section of Wrangellia less than certain. Hence, the Wallowa-Seven Devils arc cannot be treated unequivocally as an exotic orphan.

FOREARC BASIN TERRANE

The last major terrane recognized in this assemblage of oceanic and arc environments is a Triassic to Jurassic forearc basin which extends from the Snake River east to the Aldrich Mountains and covers the contact between the oceanic/mélange and the Huntington arc terranes (Brooks and Vallier, 1978; Dickinson, 1979). It is a monotonous sequence of sandstone and siltstone with minor conglomerate and rare basalts. In the east, the Weatherby Formation of this forearc terrane is juxtaposed with oceanic rocks to the north along the Connor Creek Fault, a high-angle reverse fault which trends southwest-northeast. Westward, from the Unity basin, basalts become increasingly abundant and are often pillowed, and sediments are less metamorphosed and deformed. Forearc sediments contain oceanic and arc-derived clasts and some tectonic slices (Brooks, 1979), which suggests that these rocks were deposited in an environment intermediate to both terranes during uplift and erosion of early arc- and forearc-derived rocks.

SUMMARY

The problems posed by the pre-Tertiary geology of the Blue Mountains include (1) origin of the Elkhorn Ridge Argillite in pelagic or arc environments, (2) allochthonous or in situ development of arc terranes, (3) relations between the Seven Devils and Huntington arcs, and (4) genetic relations of ophiolitic rocks to all major pre-Jurassic terranes. The subduction and/or suture-zone origin of the serpentinite mélanges and the significance of major tectonic features such as the Oxbow-Cuprum zone are key considerations for understanding the emplacement of terranes and regional tectonic history.

Coherent forearc terranes associated with present island arcs such as the Marianas (Karig, 1971; Bloomer, 1981) contain assemblages similar to the rocks found in the "oceanic" terrane, including tectonic slivers of alkalic basalts and cherts from seamounts accreted to the arc, irregularly distributed serpentinite and ultramafics which are tectonically juxtaposed with greenstones, and an assortment of shallow-water limestones. The apparent arc-related nature of the two coherent ophiolites, the widespread occurrence of detrital sediments, and the intermediate to felsic nature of many metavolcanic rocks strongly suggest that the oceanic/mélange terrane may represent a relatively coherent forearc assemblage of Permian to Jurassic age. The time and manner of accretion of these terranes to North America are subjects which require much more thought and investigation before they can be fully resolved.

ACKNOWLEDGMENTS

The writers have benefited from discussions and field excursions with many workers in northeast Oregon. The comments of H.C. Brooks, W.H. Taubeneck, and T.L. Vallier have been especially enlightening, and this paper has greatly benefited from their reviews. Idaho conodonts were identified by David Clark. Conodonts from the Greenhorn Mountains, Snake River Canyon, and Burnt River Schist were identified by Bruce Wardlaw. Claudia Regier assisted with conodont separations. D. Bostwick dated fusulinids from the Greenhorns; N.L. Silberling identified and dated ammonites and brachiopods from the southeast Wallowas. The work was partly supported by grants from the Oregon Department of Geology and Mineral Industries, W.A. Bowes and Associates, the Geological Society of America (77-281) (EDM), and Conoco (D.S.).

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NEXT MONTH:
Part II. Road log and commentary.

USGS maps from studies of Oregon Wilderness Areas available

Since 1981, the U.S. Geological Survey (USGS) has been releasing Miscellaneous Field Studies (MF) maps resulting from studies of various Wilderness Areas in Oregon. The maps that are available are listed below:

MF-1240A—*Geologic Map of the Kalmiopsis Wilderness Area, Oregon* (1981), by Page and others
MF-1240B—*Map Showing Distribution of Serpentine Minerals, Density, and Magnetic Susceptibility of Rocks from the Kalmiopsis Wilderness, Southwestern Oregon* (1981), by Barnard and others
MF-1240C—*Geochemical Characteristics of Rock Samples from the Kalmiopsis Wilderness, Southwestern Oregon* (1982), by Carlson and others
MF-1240E—*Mineral Resource Potential, Kalmiopsis Wilderness, Southwestern Oregon* (1982), by Page and others
MF-1303A—*Geologic Map of Deschutes Canyon Further Planning Area, Oregon* (1981), by Walker
MF-1367—*Geology and Mineral Resource Potential, Gearhart Mountain Wilderness and Roadless Area, Oregon* (1982), by Walker and Ridenour
MF-1379A—*Geologic Map of the Mount Hood Wilderness, Oregon* (1982), by Keith and others
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MF-1381A—*Geologic Map, Wild Rogue Wilderness, Oregon* (1982), by Gray and others
MF-1381B—*Geochemistry, Wild Rogue Wilderness, Oregon* (1983), by Peterson and Gray
MF-1381C—*Aeromagnetic Map, Wild Rogue Wilderness, Oregon* (1982), by Blakely and Senior.

These maps are available for inspection only in the library of the Portland office of the Oregon Department of Geology and Mineral Industries. They may be purchased by mail from the Western Distribution Branch, USGS, Box 25286, Federal Center, Denver, CO 80225. Price of each of the black-and-white maps is $1.25, including the cost of domestic surface transportation. □

OSU soil study examines unstable landscapes in Coast Range

Clay Mineralogy in Relation to Landscape Instability in the Coast Range of Oregon, by J.D. Istok and M.E. Harward, Department of Soil Science, Oregon State Univeristy, was published in the *Soil Science Society of America Journal*, v. 46, no. 6 (Nov.-Dec. 1982), p. 1326-1331. Because this information may be useful to many readers, we are printing the abstract of the paper below.

ABSTRACT

Field and laboratory data reported in this study indicate that the kind of mass movement and the mineralogy of the materials involved vary with the parent material. The clay fraction of debris avalanches is dominated primarily by nonexpanding layer silicates that have large particle sizes and small water-holding capacities. Dehydrated halloysite, chloritic intergrade, and mica were the common minerals in those areas underlain by sandstones and siltstones of the Tyee Formation as well as the massive basalt flow rock of the Siletz River Volcanic Series. The clay fraction of soils derived from Tertiary sandstones of the Galice and Lookingglass Formations is dominated by chloritic intergrade, chlorite, mica, and kaolinite. Serpentine, chlorite, and mica were the soil clays associated with debris avalanches on serpentinite of the Otter Point Formation. Expandable layer silicates, or those with high charge or water-holding capacity, were not major constituents of debris avalanches, although smectite and vermiculite commonly occurred in a thin layer of soil above the underlying bedrock.

The clay fraction of samples from sites undergoing failure by creep and slump consisted primarily of smectite. Smectite, chloritic intergrade, dehydrated and hydrated halloysite, and mica were the minerals commonly associated with soil creep and slump on slopes underlain by siltstones of the Tyee Formation. Montmorillonite was the major constituent of a large rotational slump at the contact between the Nye Mudstone and the sandstones of the Astoria Formation. Smectite, chlorite, and serpentine were identified in sites underlain by serpentinite of the Otter Point Formation.

The mineralogy of soils involved in earthflow consisted predominantly of hydrated and dehydrated halloysite, amorphous material, and chloritic intergrade. No difference in mineralogy could be detected between sites underlain by siltstones of the Tyee and Nestucca Formations and tuffaceous siltstones and tuff of the Siletz River Volcanic Series. Surface samples were more poorly crystallized than samples taken at lower horizons. Electron micrographs reveal an abundance of amorphous gels and "coatings" on the surface of mineral grains. The abundance of "pores" may account for the fluid behavior of these materials during failure. □

MEETINGS ANNOUNCED

The **Alaska Miners Association** has scheduled its Annual Convention and Trade Show for October 19-22, 1983, at the Hotel Captain Cook in Anchorage, Alaska. For more information, contact Alaska Miners Association, Inc., 509 W. Third Ave., Suite 17, Anchorage, AK 99501, phone (907) 276-0347.

The **Geological Society of the Oregon Country** (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Ave., Portland, OR, in Room A adjacent to the third-floor cafeteria. Upcoming meetings, topics, and speakers:

June 17—*Sketches and Slides of Oregon Wildflowers*, by Julie Kierstead, taxonomic botanist and artist for Berry Botanic Garden.

July 1—*Annual President's Campout at Mount St. Helens*, by Clair F. Stahl, 1983 GSOC President.

July 15—*Description and Locations of Field Trips on President's Campout at Mount St. Helens*, by Clair F. Stahl, 1983 GSOC President.

August 5—*Jaunting Around the Emerald Isle*, by Hazel Newhouse, retired geographer.

For additional information, contact Viola L. Oberson, Luncheon Program Chairwoman, phone (503) 282-3685. □

Send us your announcements

One of our Medford readers has suggested that *Oregon Geology* serve as a clearing house for announcements on geological training sessions, workshops, or seminars for the professional geologist.

We think that is a good idea. So if you send us notices of your meetings and training sessions, we will print them in *Oregon Geology*, space permitting. Allow at least a month and a half—and preferably two months—lead time. □

ABSTRACTS

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

STRUCTURE OF THE OXBOW AREA, OREGON AND IDAHO, by William J. Schmidt (M.A., Rice University, 1980)

The northeasterly-trending Oxbow-Cuprum shear zone is a zone of intense deformation up to 1 km wide and 8 km long located in northeastern Oregon and western Idaho. The Oxbow-Cuprum shear zone is composed primarily of metamorphosed igneous rocks (quartz diorite, gabbro, diabase, and quartz keratophyre) and their mylonized equivalents.

The rocks of the Oxbow area have experienced four periods of deformation. The first deformational event (F_{1a}) resulted in the formation of a foliation (S_{1a}) and lineation (L_{1a}). S_{1a} strikes northeast and dips steeply. L_{1a} trends northeast and is subhorizontal. Strain associated with this event is irrotational. The effects of the second deformational event (F_{1b}) are not as widespread as those associated with F_{1a}. F_{1b} structures include a subhorizontal northeast-trending intersection lineation (L_{1b}), isoclinal folds, and steep northeast-striking axial plane cleavage (S_{1b}). Strain associated with this event is rotational. During the last two deformational events (F_2 and F_3), S_1-planes were folded into open, asymmetric mesocopic and megascopic folds. Fold axes (L_2) for F_2 plunge at variable angles to the southwest. F_2 axial planes (S_2) have a shallow to moderate dip and northwesterly strike. F_3 fold axes have a moderate to steep plunge. Axial planes (S_3) for F_3 trend either north-south or east-west, dipping steeply.

F_{1a} and F_{1b} are probably the result of northwest-southeast crustal shortening. The ductile nature of F_{1a} and F_{1b}, along with the similar orientation of S_{1a} and S_{1b}, implies that these two events are related to a Triassic metamorphic event which has been dated at 220 m.y. ($^{39}Ar/^{40}Ar$ age determination). F_2 and F_3 appear to be the result of northeast-southwest crustal shortening. These two events may be related to this Triassic event or to some other deformation event (or events) which occurred prior to the Cretaceous.

Paleontological, sedimentological, and structural data indicate that the Seven Devils terrane and portions of the Central Mélange terrane were accreted to the continental margin during the Late Jurassic. The Triassic event is related to crustal shortening which occurred at some distance from the North American continent. The igneous rocks associated with the Oxbow-Cuprum shear zone (i.e. the Oxbow complex) probably represent a portion of the substructure on which the Seven Devils Group was deposited. □

STRATIGRAPHY, LITHOFACIES, AND DEPOSITIONAL ENVIRONMENT OF THE COWLITZ FORMATION, TPS. 4 AND 5 N., R. 5 W., NORTHWEST OREGON, by Dale M. Timmons (M.S., Portland State University, 1981)

The Cowlitz Formation in southern Columbia and Clatsop Counties, northwest Oregon, was studied in order to prepare a geologic map of parts of this formation and to determine the character of its lithofacies and the environments of deposition.

Extensive field and laboratory studies show the sediments of the upper Cowlitz Formation were deposited near shore in a wave-dominated environment in the Narizian. Abundance of carbonized organic remains, boulder conglomerates, and rounded volcanic sandstones exhibiting high-angle planar cross-bedding associated with the Goble Volcanics, morphology and mode of occurrence of trace fossils, especially *Thalassonides*, and presence of thick-shelled pelecypods all indicate energetic, nearshore, shallow-water deposition. Small-scale channeling and discontinuous strata suggest wave-dominated conditions with storm surge deposits. Lack of clay in some sandstones and paleontologic interpretations by other workers verify an open marine environment.

Parts of the Goble Volcanics in the area of study including Green Mountain and Rocky Point were volcanic islands in the late Eocene. Major-oxide chemistry suggests they were erupted in an orogenic (magmatic arc) environment while the Cowlitz Formation was deposited in the associated fore-arc basin.

Volcaniclastic rocks created by autobrecciation and marine fossils within these rocks show the Goble Volcanics are in part subaqueous. The presence of laterites also indicates subaerial eruption of the Goble Volcanics. High-energy conglomerate and volcanic sandstone deposits aproning the volcanic centers further exemplify shallow-water conditions. Overlying subaerial lava flows show that a shoreline is represented by the volcaniclastic and conglomerate member of the Cowlitz Formation.

K-Ar dates ranging from 32.0 ± 0.3 m.y. to 45.0 ± 1.4 m.y., occurrences of Goble-like rocks with Keasey-age rocks, and highly variable geochemistry show the Goble Volcanics occupy a long geologic time span and should be subdivided. □

STRATIGRAPHY, STRUCTURE, AND PETROLOGY OF THE LOOKINGGLASS AND ROSEBURG FORMATIONS, AGNESS-ILLAHE AREA, SOUTHWESTERN OREGON, by Raisuddin Ahmad (M.S., University of Oregon, 1981)

The early-middle Eocene Roseburg and Lookingglas Formations, named by Baldwin (1974) for exposures near Roseburg, Oregon, are also present in the Agness-Illahe area, southwestern Oregon. Only the upper part of the Roseburg Formation is exposed in this area, where it is composed principally of lithic sandstones and siltstones. The basal Bushnell Rock Member and the middle Tenmile Member of the Lookingglass Formation crop out in the Agness-Illahe area, but the Olalla Creek Member is absent. The Bushnell Rock Member is composed of two lower units of petromict conglomerate overlain by lithic sandstones and siltstones. The Tenmile Member is composed entirely of lithic sandstones, siltstones, and minor shale.

Petrographic study of the formations indicates that the Roseburg and Lookingglass sandstones and siltstones were derived from a mixed provenance of Klamath Mountain mélange terrane and Cascade Mountain volcanic arc, and the Bushnell Rock conglomerates were derived largely from the Klamath Mountains.

Petrographic data together with some regional paleotectonic information provided by previous workers suggest that the Roseburg and Lookingglass sandstones and siltstones were deposited by turbidity currents in forearc basins. Based on descriptive physical and biological features and the overall stratigraphic context, two depositional models are indicated for the Bushnell Rock conglomerates: a fluvio-neritic model for the lower unit, and a trench-slope model for the upper unit.

REFERENCE CITED

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