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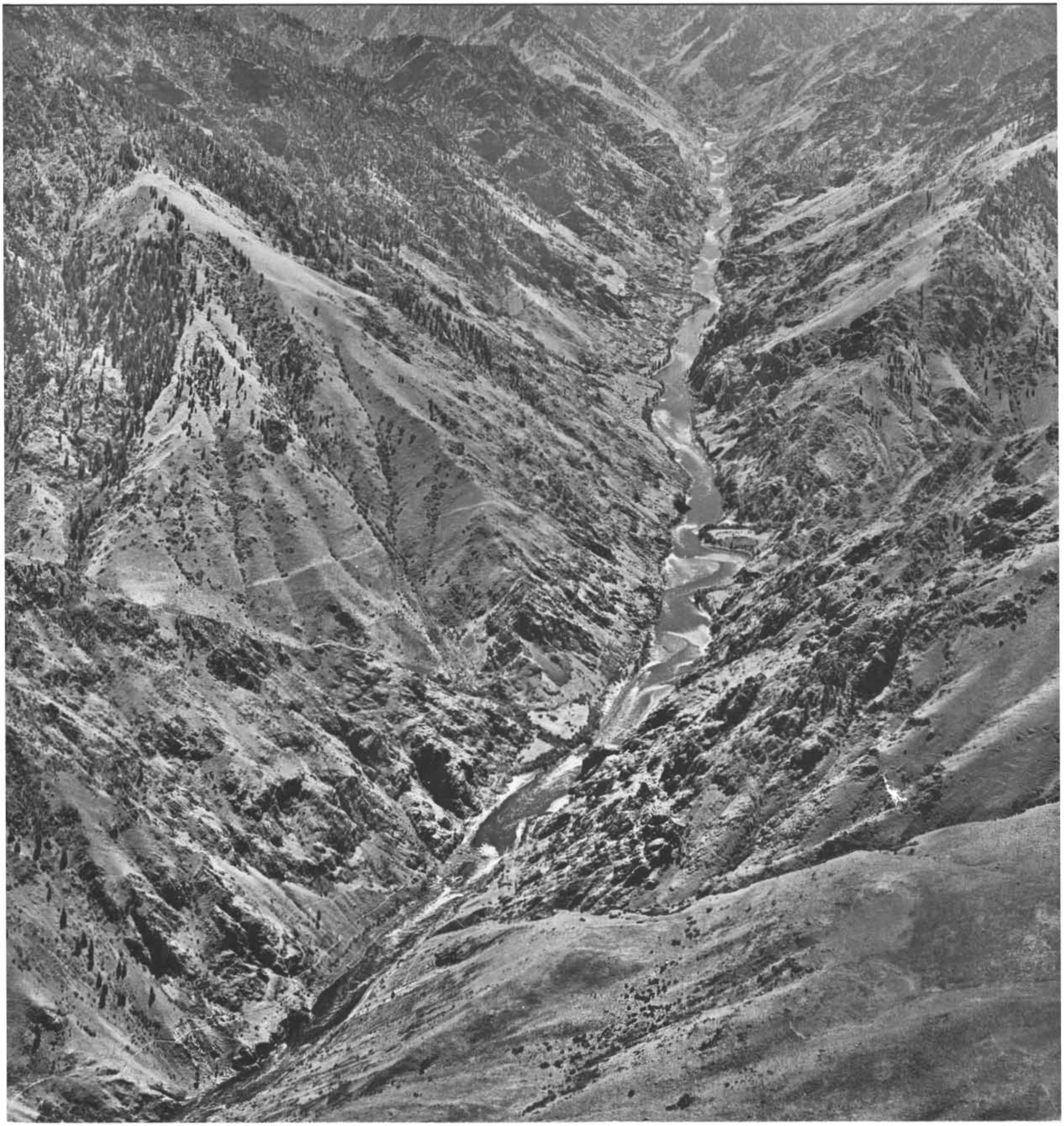

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COVER PHOTO

Aerial view of Hells Canyon of Snake River, looking upriver to south near Hat Point. Saddle Creek is in right middle ground. Rocks are primarily pre-Tertiary volcanic and volcaniclastic rocks of Wallowa-Seven Devils volcanic arc terrane (see article beginning p. 71). (U.S. Forest Service photo)

NOTICE TO CONTRIBUTORS

OREGON GEOLOGY readers are invited to submit articles about Oregon geology, such as field trip guides, descriptions of geology of state parks, results of student or faculty research, and information on interesting mineralogical or paleontological finds. Both technical and general interest articles will be published. Authors of technical articles are urged to obtain peer review prior to submittal, and such reviewers should be acknowledged in the article.

1. All material should be typewritten, double-spaced, with one-in. margins.
2. In general, articles, including tables, artwork, and photos should not exceed 20 pages in length. Longer articles might be published in two installments.
3. Drafted material must be submitted in final form. If reduction will be necessary, lettering should be large enough to be legible after reduction.
4. Photos should be black-and-white glossy prints. If slides or color prints are the only photos available, consult with the editor.
5. All artwork and photos must be clearly marked. Figure references should be placed in appropriate places in the text. A separate typed list of figure captions should accompany the article. All artwork and photos become the property of the Department, unless other arrangements are made prior to publication.
6. Consult U.S. Geological Survey *Suggestions to Authors* (6th ed.) for questions of style. Authors are responsible for accuracy and completeness of citations.
7. Except for units of measurement, do not abbreviate.
8. Authors (or first author in the case of multiple authorship) will receive 25 complimentary copies of the issue of OREGON GEOLOGY in which their article appears.

* * *

TO OUR READERS

Readers will note that this month's issue of Oregon Geology has been typeset. We are trying typesetting because we believe it will increase our efficiency, improve readability, and enable us to get much more information onto each page. We invite your comments on this new step.

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Plate Tectonics and the Geologic History of the Blue Mountains

by H.C. Brooks, Resident Geologist, Baker Field Office, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Rocks which make up the Blue Mountains of northeastern Oregon and adjacent western Idaho are divided into two main groups on the basis of their geologic ages and origins. The older of the two groups ranges from Devonian to Late Jurassic in age and is made up chiefly of rocks which at one time were part of an ancestral Pacific Ocean. According to plate tectonic theory, these rocks represent fragments of ancient ocean floor and volcanic islands that were broken up, moved across some unknown breadth of ocean, and added onto what was then the outer edge of the continent. This accretionary expansion of the continent took place between Late Triassic and Late Jurassic time.

The younger group of rocks is of Cenozoic age and consists of sedimentary and volcanic rocks that were deposited on dry land or in freshwater lakes on top of the older rocks after they had become part of the continent. Erosion has removed the Cenozoic rocks in many places, exposing pre-Cenozoic rocks.

In this report only the pre-Cenozoic rocks are discussed. Preceding the discussion is an outline of some basic concepts of plate tectonics for those readers who are not familiar with the subject. The interested reader is encouraged to consult recent geologic textbooks for more thorough discussions of the theory.

This discussion of plate tectonics and the Blue Mountains is largely a synthesis of information presented in recent publications by Brooks and others (1976), Vallier and others (1977), Thayer (1977), Vallier (1977), Brooks and Vallier (1978), Dickinson and Thayer (1978), Hamilton (1976; 1978a, b), and Dickinson (1979).

PLATE TECTONIC THEORY

The basic tenet of the theory of plate tectonics is that the outer rind of the earth is divided into giant plates that are in motion relative to one another (Figure 1). The plates are rigid and float on a relatively plastic and deformable substratum. They are about 80 km thick and comprise the outermost layer of the earth (the crust) and the upper part of the underlying layer (the mantle).

This rigid outer portion of the earth is called the lithosphere. The plastic layer on which the lithospheric plates move is lower in the mantle and is called the asthenosphere.

All of the lithospheric plates are moving more or less continuously—pulling apart, pushing together, slipping past or sliding under one another like ice floes in a river. They are constantly changing in size and shape. Zones with frequent earthquakes outline the boundaries of the plates. Motion of the plates results in relative displacements between adjacent plates ranging from less than 1 to about 13 cm per year. The velocities are unimpressive until one realizes that 5 cm per year amounts to 50 km per million years, and some plate movements have been under way for at least 100 million years.

Where plates are moving away from one another, hot plastic material (magma) from the mantle flows upward to fill the fissures which open between them and solidifies to become part of the trailing edges of the separating plates (Figure 2). New crust is thereby created. Because most of the rift zones where plate material is being created are in the middle of the ocean floor, this process is called sea-floor spreading. Presently, the plates are separating and gaining new material primarily along a system of submarine ridges more than 64,000 km in total length that branches through all the world's oceans like the seam of a baseball. A ridge forms between the separating plates because the new material is hot, lower in density, and rides relatively high on the asthenosphere. As the plates move apart, the material cools, becomes higher in density, and rides lower on the asthenosphere.

Where the plates converge, one is deflected downward so that it slides beneath the leading edge of the other and then is carried back into the earth, where it is recycled. Old crust is thereby destroyed. Overall plate consumption must progress at the same rate as plate growth. Generally, oceanic plates slide beneath continental plates or other oceanic plates.

As the oceanic plates move about, they accumulate an overlayer of sediments consisting partly of material eroded from continents and islands and partly of the remains of oceanic micro-organisms. When the cooled oceanic plate with its overlying layer of sediment is carried down into the hotter mantle at subduction zones, selective melting of the lighter materials, including the sediment, occurs.

Part of the melted material rises and reaches the surface of the overriding plate, producing a zone of volcanic activity called a volcanic arc; part of it crystallizes before reaching the surface, either in the roots of the volcanoes or in the crust beneath them (Figure 2).

Large intrusive bodies of rock that crystallize underground from a melt are called plutons; large plutons (over 100 sq km in area) are called batholiths, and smaller ones are called stocks. Sheetlike intrusive igneous rocks that cut across the planar structure of surrounding rocks are called dikes; those that parallel the structure are called sills.

As the oceanic crust descends beneath the volcanic arc, it provides a replenishable source of magma so that the volcanic (extrusive) and plutonic (intrusive) buildup of the arc may continue for many millions of years. Volcanic arcs may form on the floors of ocean basins or along continental margins, depending on the locations of the subduction zones. Offshore volcanic arcs often appear as strings of volcanic islands known as island arcs. The Pacific Ocean is ringed with island arcs. The Aleutian Islands and the Japanese Islands are prime examples. The Andes Mountains of South America and the Cascade Mountains of Oregon and Washington are examples of volcanic arcs that are built on continental margins.

Subduction zones are marked by trenches, great linear depressions in the ocean floor. Trenches are repositories for accumulations of sediment derived mainly from overriding plates. Sediment deposited on a trench floor is carried beneath the margin of the overriding plate by the descending plate unless the rate of sediment accumulation exceeds the rate of subduction, in which case part of the sediment piles up against the wall of the trench.

The parts of a growing volcanic arc which rise above sea level are subjected to erosion; as a result, volcanic and sedimentary rocks are mixed and interlayered. Some sediment is carried toward the ocean and deposited in the area between arc and trench. This area is known as the arc-trench gap or forearc basin. Also, some sediment is carried toward the continent and deposited between the arc and the continent.

The continents and ocean basins are distinctly different parts of the plates and are affected differently during plate movements. Nearly all plates consist of both continental and oceanic portions that move together as a unit. Because it is made of lighter material, continental crust is much thicker than oceanic crust, and for the same reason, continents stand higher than ocean basins. Oceanic crust is generally about 5 km thick. Average thickness of continental crust is about 35 km; thickness under mountain ranges may be as much as 60 km.

Sooner or later, all ocean floors will be replaced as new crust is created at spreading ridges and old crust is consumed in subduction zones. The most ancient segment of the present ocean floor anywhere in the world is less than 200 million years old, whereas some parts of the continents are more than 4 billion years old. Presumably, continental crust is too buoyant to be resorbed into the mantle at subduction zones.

Continents may split and the pieces may drift apart as new oceanic crust is formed between them. Continents on opposite sides of a spreading ridge move farther apart as new oceanic crust is created at the spreading ridge. Continents on opposite sides of a subduction zone move closer together as old oceanic crust is consumed in the subduction zone. Where oceanic crust disappears between them, continents are slowly jammed together with such deforming force that mountains are formed. The Himalayan and Alpine Mountains are examples of mountains formed by colliding continents. In the same manner, island arcs collide with continents and become part of mountain belts along the margins of continents. Continents may grow by the magmatic construction of volcanic arcs along their margins and by the accretion of volcanic arcs which were constructed on the ocean floor. There are no ancient arcs in the present oceans, just as there are no really ancient ocean floors. All old island arcs have presumably become parts of the continents.

Associated with arc volcanic and related rocks in many mountain belts are suites of rocks called ophiolites, generally regarded as remnants of oceanic crust and upper mantle which were not totally consumed at subduction zones. Major components of intact ophiolite successions are, from bottom to top, peridotite, gabbro, basalt, and oceanic sediments. Many ophiolite successions also include quartz diorite and albite granite (plagiogranite) in the upper part of the intrusive complex and keratophyre and quartz keratophyre lava and tuff in the extrusive sequence. Most ophiolite sequences are capped by fine-grained sedimentary rocks, usually including chert and argillite which were deposited in layers on top of the oceanic crust as it moved away from the spreading ridge.

The mountainous region of the western United States west of the Rocky Mountains is known as the Cordilleran Orogen. The Cordillera is divided into two belts which roughly parallel the present Pacific continental margin. The eastern belt consists mainly of marine sedimentary rocks derived from erosion of continental rocks and deposited on the continental margin. The western belt is made up mainly of fragments of oceanic crust and volcanic arcs and their associated sedimentary terranes that were swept against the continent on moving oceanic lithosphere. The approximate location of the continental margin at different times during the Mesozoic is shown in Figure 3.

Pre-Cenozoic rocks in the Blue Mountains are among the easternmost exposures of the western belt of accreted terranes. Oceanic crust (ophiolite) and volcanic island arc terranes of the Blue Mountains region were accreted to the continent during the Late Triassic to Early Cretaceous interval of geologic time. The contact between these rocks and rocks of the eastern, nonvolcanic portion of the Cordillera is obscured by the Idaho Batholith, of Late Cretaceous and younger age.

PLATE TECTONIC TERRANES IN THE BLUE MOUNTAINS

Pre-Cretaceous rocks in the Blue Mountains are divided into four terranes: oceanic crust terrane, Wallowa-Seven Devils volcanic arc terrane, Huntington volcanic arc terrane, and forearc basin terrane. The rocks in all terranes are metamorphosed to varying degrees and intruded locally by late Mesozoic granitic plutons. Devonian through Jurassic rocks are present, but rocks ranging from Permian through Jurassic age are most abundant.

Oceanic crust terrane

The oceanic crust terrane represents oceanic crust and its overlying (supracrustal) cover, consisting of sedimen-

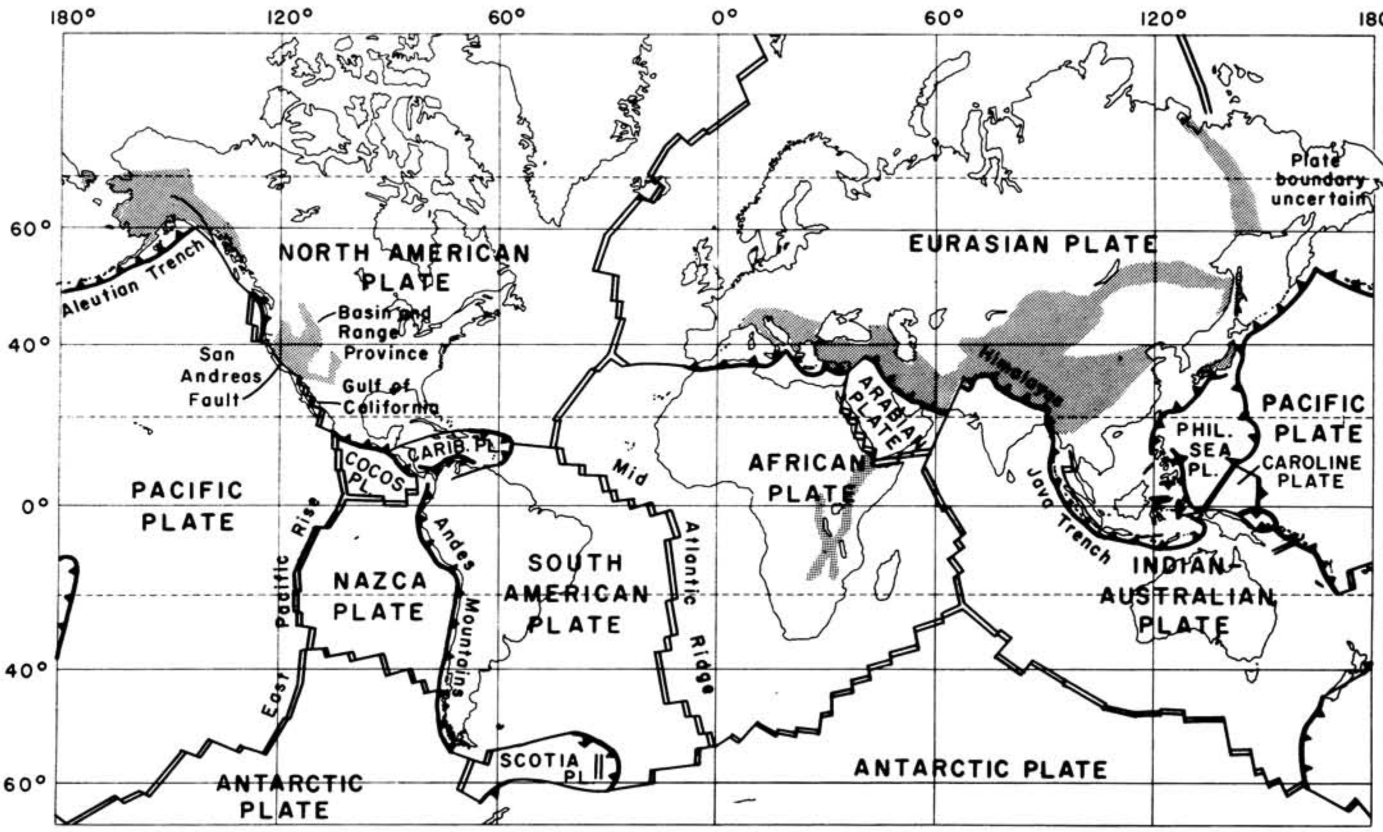


Figure 1. Lithosphere plates of the world, showing presently active boundaries. Double line: zone of spreading, where plates are moving apart. Line with barbs: zone of underthrusting (subduction), where one plate is sliding beneath another; barbs on overriding plate. Single line: strike-slip fault, along which plates are sliding past one another. Stippled area: part of a continent, exclusive of that along a plate boundary, which is undergoing active extensional, compressional, or strike-slip faulting. Compiled and adapted from many sources; much simplified in complex areas. (From Hamilton, 1978. Map courtesy California Division of Mines and Geology)

tary and volcanic rocks. Both crust and cover were severely broken up, rearranged, and deformed before and during late Mesozoic time, when the terrane became attached to the western edge of North America. Fragments of ophiolite successions are scattered throughout the terrane.

Included in the ophiolite fragments are ultramafic rocks, gabbro, quartz diorite, and albite granite in various proportions in different places. The supracrustal sedimentary and volcanic rocks are mainly chert, argillite, tuff, and lava flows, with scattered pods and lenses of limestone. Tectonic blocks of limestone and chert have yielded fossils ranging from Devonian to Middle Triassic age. Therefore, the oceanic crust terrane probably does not represent a single piece of ocean floor that has been broken up. More likely it represents a collage of pieces of several different generations of crust, broken and deformed both before and while they were being assembled by plate tectonic forces, probably near a subduction zone. Most of the rocks are severely deformed by folding and faulting. Major rock types typically are separated by faults or shear zones rather than depositional or intrusive contacts. The term "mélange" is often used to describe the chaotic mixture of rock types.

The largest intact exposure of the ophiolitic rocks is centered in Canyon Mountain, southeast of John Day (Figure 4), and is known as the Canyon Mountain Complex (Thayer, 1963). The rocks of this complex and their stratigraphic and structural relationships have been discussed in considerable detail (Thayer, 1963, 1977; Thayer and Brown, 1964; Avé Lallemant, 1976). The complex is 17 to 20 km long by 8 to 13 km wide and is about 150 km^2 in area. A block of serpentinized peridotite and gabbro that has been intensely deformed at high temperature forms 80 percent of the complex, and a sheeted dike complex makes up the remaining 20 percent. The complex is divided into three east-west belts with ultramafic rocks on the north, gabbro in the middle, and the sheeted dike complex of quartz diorite, albite granite, and keratophyre on the south. The sheeted dike complex was intruded into the peridotite and gabbro of the Canyon Mountain Complex and is believed to constitute the substructure of volcanoes that formed on the ocean floor in Permian and early Mesozoic time. Ages obtained from radioactive isotope dating of the Canyon Mountain Complex and associated metamorphic rocks nearby range from 250 to 186 million years.

Other large exposures of ophiolitic rocks occur in the Virtue Hills and Sparta areas east of Baker. East of Elkhorn Ridge, the rocks are mostly gabbro, quartz diorite, and albite granite. Ultramafic rocks make up a very small percentage of the total outcrop area.

The mix of rock types in the supracrustal assemblage

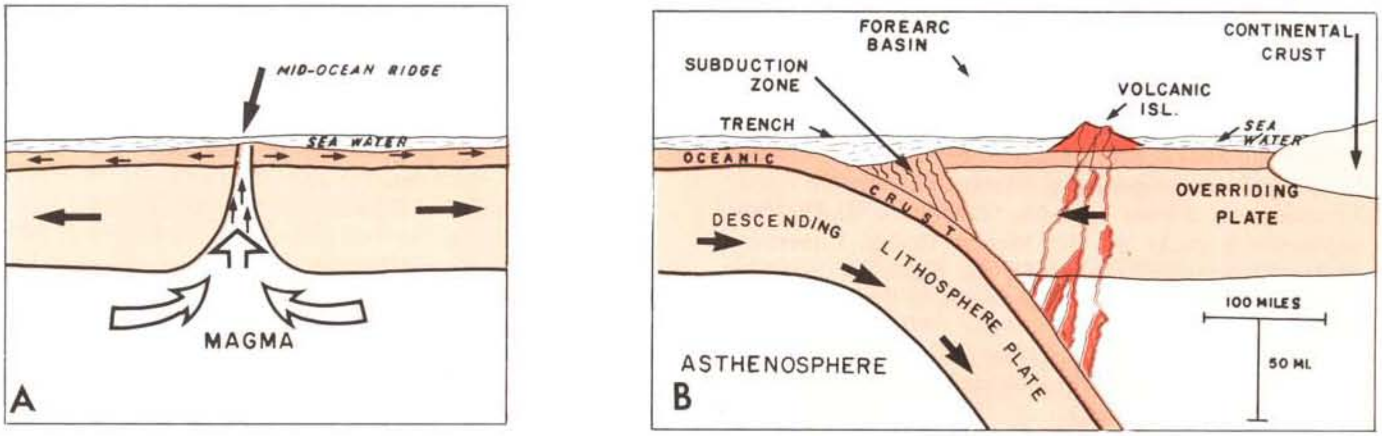


Figure 2. Schematic models of separating and converging plates of oceanic lithosphere.

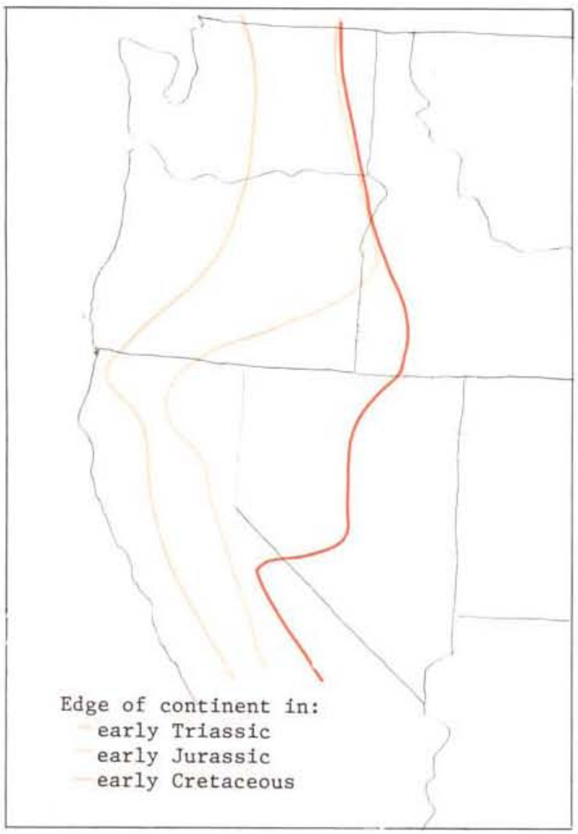


Figure 3. Map showing locations of continental margin at different times during the Mesozoic.

Figure 4. (opposite page) Geologic map showing areal distribution of pre-Cenozoic oceanic crust, volcanic arc and forearc basin terranes, and late Mesozoic plutons in Blue Mountains. Lines A-A' and B-B' show approximate locations of cross sections in Figure 5.

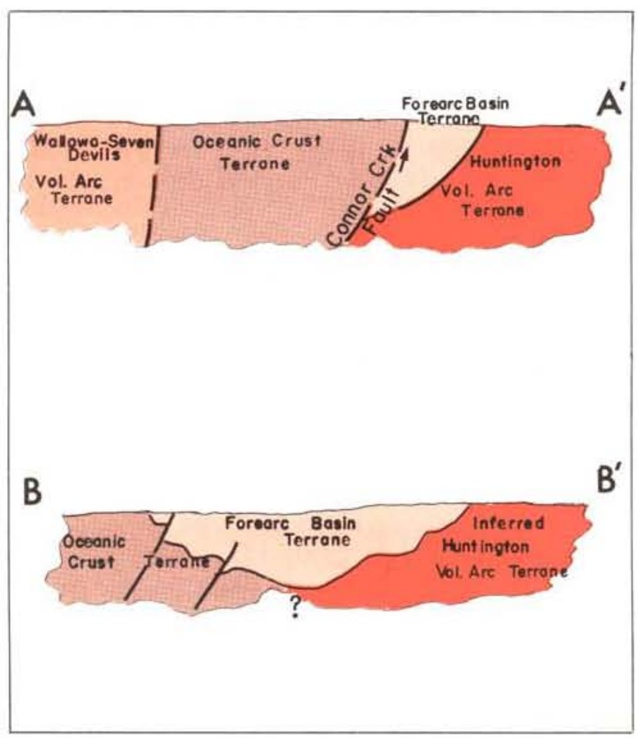
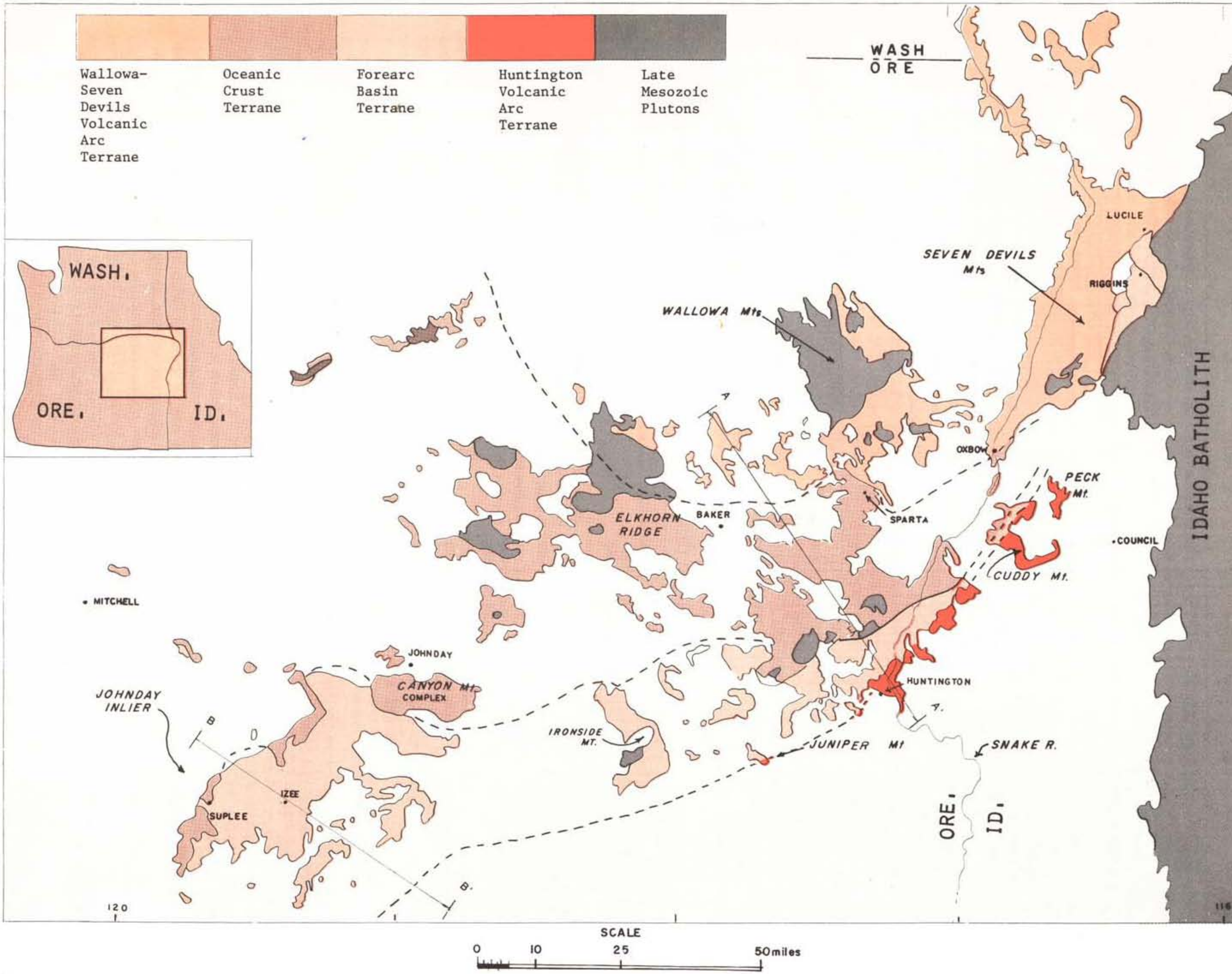


Figure 5. Schematic cross sections illustrating the inferred relationships between the terranes in Figure 4. See Figure 4 for location of lines A-A' and B-B'. Cenozoic cover and Mesozoic plutons are not shown.


Wallowa-Seven Devils Volcanic Arc Terrane
Oceanic Crust Terrane
Forearc Basin Terrane
Huntington Volcanic Arc Terrane
Late Mesozoic Plutons
WASH
ORE
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ID.
SEVEN DEVILS Mts
WALLOWA Mts
LUCILE
RIGGINS
IDAHO BATHOLITH
OXBOW
PECK Mt.
SPARTA
ELKHORN RIDGE
BAKER
COUNCIL
CUDDY Mt.
MITCHELL
JOHN DAY
CANYON Mt. COMPLEX
HUNTINGTON
JOHNDAY INLIER
IRONSIDE MT.
JUNIPER Mt
SNAKE R.
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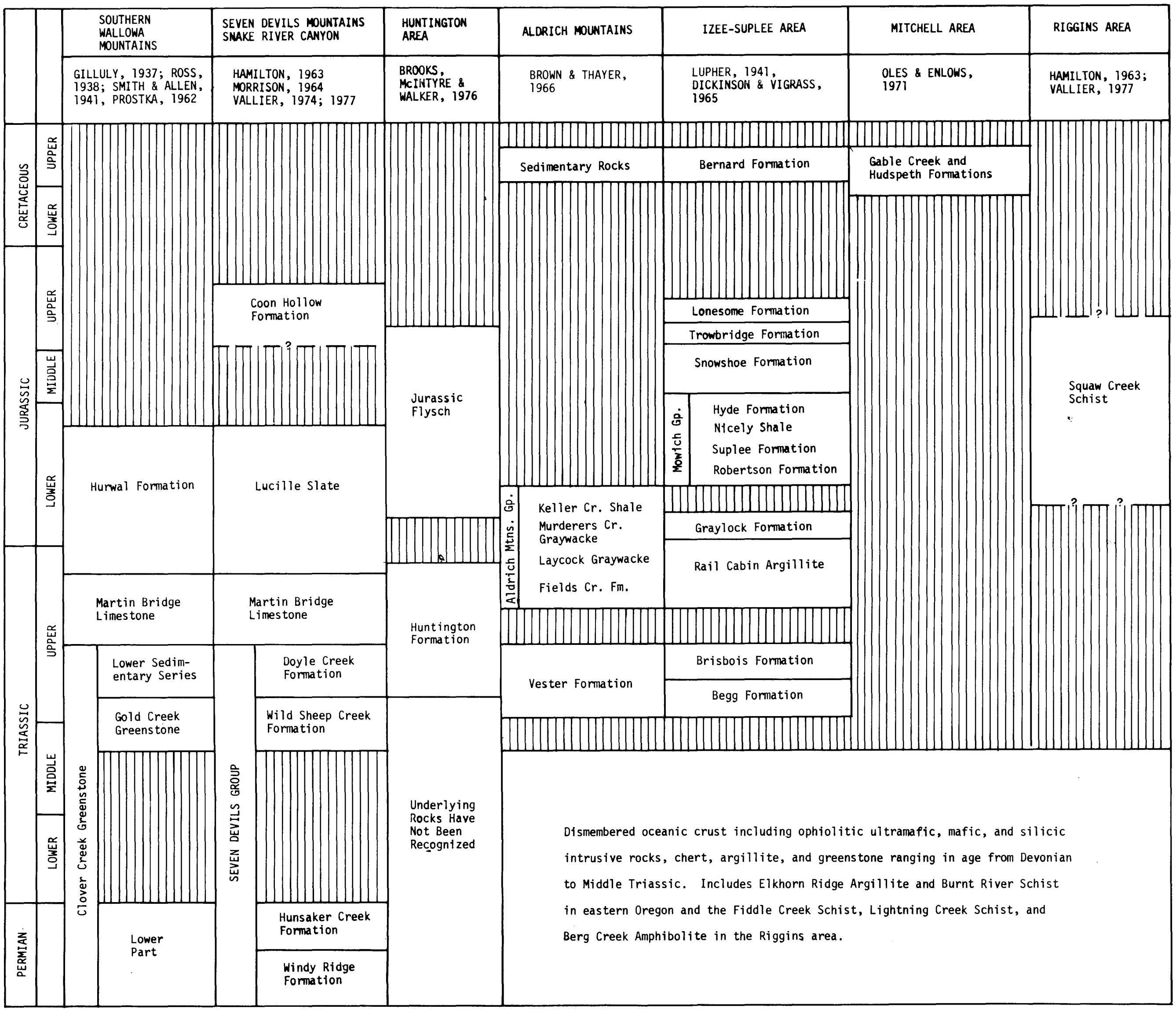

Figure 6. Mesozoic correlation chart for key Blue Mountains areas.

The relationship between the Huntington arc terrane and the Wallowa-Seven Devils volcanic arc terrane is not clear. The contact between the two is buried beneath Cenozoic lavas south of the Seven Devils Mountains. They may be parts of the same volcanic arc or parts of different, possibly widely separated, arcs brought close together by plate movements.

Forearc basin terrane

The forearc basin terrane is represented by a great thickness of mainly clastic strata between the dismembered oceanic crust terrane and the Huntington arc terrane. Rocks of the forearc basin conceal the contact between the oceanic and arc terranes (Figure 5). Deposition occurred in Late Triassic to Late Jurassic time. The strata have an aggregate thickness of 15,000 m. Dominant rock types are sandstone, siltstone, shale, and tuff, with subordinate lava flows and scattered limestone and conglomerate beds. Most of the clastic rocks are made up largely of detritus eroded from volcanic rocks; some consist mainly of chert grains, and some consist of water-laid tuff.

In the Snake River area, Lower Jurassic beds of the forearc basin terrane rest unconformably on the Upper Triassic volcanic rocks of the Huntington arc terrane and are in contact with rocks of the dismembered oceanic crust terrane along the Connor Creek fault. These rocks comprise the "flysch terrane" of Brooks and Vallier (1978) and the "Jurassic flysch" of Figure 6. The term "flysch" is used in its broad sense, to mean an extensive sedimentary formation derived by rapid erosion of an adjacent rising land mass.

A conglomeratic unit at the base of the flysch is made up largely of rounded fragments of volcanic rocks eroded from emergent parts of the Huntington arc terrane and deposited on its submerged flanks. Some of the rocks contain fragments of granitic rocks from the plutonic core of the volcanic arc. The much thicker sequence of sandstone and siltstone overlying the conglomerate represents deposition of finer grained erosional debris that was transported farther from shore.

The presence of erosional and tectonic fragments of oceanic rocks in the flysch indicates that rocks of the oceanic crust terrane formed the north wall of the basin in which the flysch was deposited. The Connor Creek fault is a high-angle reverse fault along which rocks of the oceanic crust terrane have been uplifted and shoved southeastward over part of the flysch. The attitude of the fault and the shear cleavage in the flysch are approximately parallel, suggesting that movement on the fault and deformation of the flysch were related and involved compression of the flysch against the Huntington arc.

The southwestern portion of the forearc basin terrane south and southwest of John Day is commonly called the John Day inlier. Mesozoic clastic rocks in that area are only weakly metamorphosed and not greatly deformed. Consequently, a wealth of stratigraphic detail has been developed. Fossils have been collected from hundreds of localities in Mesozoic strata for which about 25 formal stratigraphic names are currently valid. At least six unconformities break the stratigraphic sequence, and many of the units are thin and have limited lateral extent. Stratigraphic columns for the Aldrich Mountains and Izee-Suplee areas of the inlier are shown in Figure 6.

Most of the Mesozoic sandstones throughout the inlier contain sedimentary detritus from rocks typical of volcanic island arcs. A likely source for some of the volcanic detritus is the Huntington volcanic arc. The Huntington arc terrane is not exposed southwest of Juniper Mountain (Figure 4), but a southwestward extension of it is inferred to exist beneath Tertiary rocks southeast of the John Day inlier. High in the sequence are water-laid tuffs that are younger than any dated rocks in the Huntington arc terrane, indicating that there were additional volcanic sources. Some of the Upper Triassic rocks in the lower part of the sequence were deposited on rocks of the oceanic crust terrane, from which the sediments were in part derived. Rocks in the middle and upper levels of the sequence are made up largely of detritus derived from the kinds of rocks which are typical of volcanic island arcs. The occurrence of lava flows and other products of active volcanoes in places within the John Day inlier indicates that active volcanoes were not far away.

CONCLUSIONS

The oceanic crust and island arc terranes exposed in the Blue Mountains were accreted to the continent between Late Triassic and Middle Cretaceous times. Present indications are that both volcanic arc terranes are of intra-oceanic origin and therefore could not have been accreted to the continent until after the youngest associated rocks were deposited. The youngest dated rocks in the Huntington arc terrane are of Late Triassic (Norian) age. The youngest rocks in the Wallowa-Seven Devils arc terrane are clastic strata of Early Jurassic (Pliensbachian) age.

Mid-Cretaceous sedimentary rocks in the western part of the province contain erosional debris from the oceanic crust and forearc basin assemblages and from Mesozoic plutons and are therefore believed to have been deposited after the older terranes became attached to the continent. Clearly all the pre-Cenozoic terranes had been deeply eroded prior to the deposition of the oldest continental volcanic and sedimentary rocks in early Tertiary time.

The pre-Cenozoic rock assemblages in the Blue Mountains represent small parts of a very large plate tectonics jigsaw puzzle that can never be entirely reconstructed because some of the pieces are missing or are obscured by younger rocks and tectonic events. Some of the major questions remaining to be answered involve the identification of the substructure of the arc terranes, determination of the structural relationships between the oceanic crust and island arc terranes, and resolution of the problem of whether the two arc terranes are parts of the same arc or juxtaposed fragments of different arcs.

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AMENDED OIL AND GAS RULES

Amended Oil and Gas rules are in the process of being printed at the Secretary of State's office but will not be available for at least several weeks. Therefore the Oregon Department of Geology and Mineral Industries has had the amended rules printed and is circulating them so they may be referred to in the interim. These amendments are available from the Department's Portland office for $0.75 to cover the cost of handling and mailing.

The amendments, plus the existing rules, comprise a complete set of oil and gas regulations. □

ABSTRACTS

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

STRATIGRAPHY AND PETROGRAPHY OF THE SELAH MEMBER OF THE ELLENSBURG FORMATION IN SOUTH-CENTRAL WASHINGTON AND NORTH-CENTRAL OREGON, by Mavis Hensley Kent (M.S. in Geology, Portland State University, 1978)

The Selah Member of the Ellensburg Formation is a sedimentary interbed within lava flows of Yakima Basalt and occurs in south-central Washington and north-central Oregon. The Selah Member is overlain by the Pomona Member of the Saddle Mountains Basalt and underlain by the Priest Rapids Member of the Wanapum Basalt. The Selah Member has been studied in detail within the southwestern portion of the Columbia Plateau, in the Roosevelt-Arlington basin, an east-west trending structure which parallels the axis of the Dalles-Umatilla syncline. The Roosevelt-Arlington basin is bounded by the Horse Heaven Hills anticline to the north, and the Willow Creek monocline to the south.

Within the Roosevelt-Arlington basin the Selah Member is divided into three lithologic and petrographic units. The lowermost unit, I, consists of air-fall tuff, accretionary lapilli tuff, pumicite, and minor volcanic litharenite and siltstone. The middle unit, II, is subdivided into: (1) a northern part consisting primarily of volcanic lith-arenite, feldspathic volcanic lith-arenite and basaltic conglomerate, which is referred to as the tectonic facies; and (2) a southern part consisting primarily of claystone and siltstone, referred to as the lacustrine facies. The uppermost unit, III, consists of water-lain siltstone, volcanic lith-arenite, vitric (volcanic) lith-arenite, and minor pumicite and accretionary lapilli tuff.

The light mineral assemblage (<sp gr 2.96) in the Selah member consists of altered vitric (devitrified ash) rock fragments (up to 99.8 percent by volume), sanidine feldspar, glass, plagioclase feldspar, and quartz, and indicates abundant primary volcanic air-fall sources. The heavy mineral assemblage (>sp gr 2.96) consists of opaques, hypersthene, hornblende, basaltic hornblende, clinozoisite, epidote, topaz, and zircon, and also indicates a primary volcanic source. Plutonic/metamorphic minerals comprise less than 5 percent of the heavy mineral assemblage, and commonly less than 0.5 percent of the total mineral volume.

Explosive volcanic activity during Selah time, probably in the Cascade Range to the west, was a major source of the tephra that were deposited in streams and shallow lakes within the Roosevelt-Arlington basin. Penecontemporaneous deformation during Selah-time, probably associated with the major structural features bounding the Roosevelt-Arlington basin, is suggested by the presence of basaltic conglomerates and an erosional unconformity at the base of unit II-tectonic facies. The absence of the ancient Columbia River in the Roosevelt-Arlington basin during deposition of the Selah Member is indicated by the structural and/or topographic isolation of the Roosevelt-Arlington basin, the lack of quartzitic gravels, and the low volume of plutonic/metamorphic sediments. It is suggested that the Columbia River occupied a northerly course during deposition of the Selah Member.

THE STRATIGRAPHY AND STRUCTURE OF THE COLUMBIA RIVER BASALT IN THE CLACKAMAS RIVER DRAINAGE, by James Lee Anderson (M.S. in Geology, Portland State University, 1978)

The Clackamas River drainage within the western Cascade Range is approximately aligned with a northwest trending lineation defined by the Portland Hills and the Brothers Fault zone. This area is occupied by an extensive Columbia River Basalt sequence that is deeply incised by the Clackamas River and its tributaries. Two major basalt units of the Yakima Basalt Subgroup, including the Grande Ronde Basalt and the Frenchman Springs Member of the Wanapum Basalt, are distinguishable in a 515 m to 550 m accumulation. Of particular interest is the presence of five distinct geochemical and paleomagnetic subunits within the Grande Ronde Basalt. These include, from oldest to youngest, the paleomagnetically normal (N_1) low Mg0, reversed (R_2) low Mg0, reversed (R_2) Prineville, normal (N_2) low Mg0, and normal (N_2) high Mg0 geochemical types. Interbeds having wide lateral extent and ranging in thickness from 3 to 35 m are numerous, indicating close proximity to a degrading highland. Composition of these units indicates contemporaneous Cascadian volcanism.

The structural grain of the area is primarily northwest with lesser northeast and north-south components. A general northwest dip of less than 10° predominates and reflects Cascadian uplift. Northwest faults cut the shallowly dipping Columbia River Basalt sequence in an en echelon pattern that is distributed across the entire area. Sense and magnitude of movement on all faults are highly varied. Both strike-slip and dip-slip faulting have been recognized, with the throw on normal faults commonly ranging between 100 and 200 m. Graben structures are defined by faults in both the Fish Creek Airstrip and Roaring River areas. The basalt is most deformed along the northeast margin of the area where dips of 10° to 35° occur. An anticlinal fold is indicated by attitudes in the Roaring River area. Folding over the rest of the Clackamas River study area is of a very broad nature. Vertical fault planes, orientation of structures, and the presence of northwest trending right-lateral strike-slip faults are consistent with a stress model of north-south compresion and east-west extension. □

meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach this office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

NATIONAL AEG PRESIDENT TO SPEAK

The Oregon section of the Association of Engineering Geologists will meet Thursday, May 17, at the Tualatin Ramada Inn (I-5 at the SW Nyberg Road exit). Underground tunneling will be the subject of the evening's talk by national AEG president Richard J. Proctor, Metropolitan Water District, Los Angeles, California. Social hour will be at 6:00 p.m., dinner at 7:00, and meeting at 8:00. For more information about the meeting, call Mavis Kent (635-4419). For dinner reservations, call Lew Gustafson (221-6460) or Jack Richards (221-3867).

GSOC LUNCHEON TALKS ANNOUNCED

The Geological Society of the Oregon Country holds noon luncheon meetings on the first and third Fridays of each month in Room A, adjacent to the cafeteria, third floor, Standard Plaza, 1100 SW 6th Avenue, Portland. Upcoming topics and speakers include:

May 18: **ENERGY FOR THE FUTURE,** talk by Harry T. Moorefield, office supervisor, Portland region, Atlantic Richfield Co.

June 1: **SANDY RIVER GORGE,** talk by Tom McAllister, Outdoor Editor, Oregon Journal.

June 15: **SOUTHEAST RELIEVING SEWER: EAST PORTLAND,** talk by Robert L. Gamer, Senior Geologist, Foundation Sciences, Inc.

For additional information, contact Viola Oberson, Program Chairman (282-3685). The meetings are open to the public. No reservations are required. □

"You'd better make a decision soon. The continents are starting to drift apart."

(C) Punch-ROTHCO

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