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The Columbia River Basalts

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Knowledge of the dynamic processes controlling the formation and evolution of the earth's crust has greatly increased over the last two decades. Today we are aware that the 10-kilometer-thick crust beneath the oceans is composed primarily of basalt, which is being extruded in a continuing process along a worldwide network of ocean ridge-rift systems such as the Mid-Atlantic Ridge and the East Pacific Rise (*1*). Basalt is generated by the melting of the less refractory part of the upwelling, ultramafic mantle that underlies the crust. Basaltic (mafic) crust so formed is displaced by still newer crust and moves laterally away from the ridges until it descends again to the mantle along subduction zones, where the crust plunges beneath continental margins (as along the western coast of South America), or under island arc systems such as those that flank the western Pacific from the Aleutian Islands to Indonesia.

Summary. Between 17 million and 6 million years ago, 200,000 square kilometers of the American Northwest were flooded by basaltic lava that erupted through fissures in the crust up to 150 kilometers long. Larger individual eruptions covered over a third of the Columbia Plateau in a few days. The lavas represent partial melts of the earth's mantle that were only slightly modified by near-surface, upper crustal processes. The abundant chemical and mineralogical data now available offer an opportunity to study mantle composition and the processes involved in the evolution of the earth's crust.

In the subduction process the wet basaltic ocean crust undergoes a second partial melting as it descends to zones of higher temperature and pressure. The least refractory portion melts again and moves toward the surface as lava with the average composition of andesite (containing more SiO_2, Na_2O, and K_2O than basalt, but less MgO and FeO), while the heavier solid residue continues deeper into the mantle. Rocks of andesite composition, which are less dense than basalts, resist later subduction and accrete on the surface to form the continents.

The total effect of this continuing process of plate tectonics (*1*) is a progressive differentiation of the earth's mantle by a thermal convection system that has operated since the earth's origin more than 4.5 billion years ago. It results in the less refractory and less dense components moving toward the earth's exterior and the more dense components migrating nearer to the earth's center. The less dense crust floats on the earth's mantle. The continental crust, which is both less dense and thicker than the oceanic crust, is largely exposed above sea level.

Formation of new oceanic crust along the length of an ocean ridge-rift system involves the addition of very large volumes of basaltic rock, much of which reaches the ocean floor as lava fed by the deep fissures of the rift system. This activity is normally hidden beneath the oceans. Sporadically through geologic time, similar basalt eruptions have penetrated the continental crust, perhaps at the beginning of a new convection cycle when the hot, upwelling part of the convection cell in the mantle moves under a continent, where its activity may eventually break the continent apart to form new oceanic crust between the separated continental fragments. Alternatively, a smaller secondary convection system may develop behind an island arc (back-arc spreading).

Although of shorter duration than ocean floor eruptions, production of continental flood basalt may be equally rapid, providing large volumes of very fluid basaltic liquid which reach the surface along fissures in the crust. The fluidity of the basaltic lava and its unusually (*2, 3*) high rate of eruption result in sheets of basalt that cover many thousands of square kilometers and build large basalt plateaus. The basalt plateaus contrast with the familiar volcanic cones formed by the more viscous and less voluminous andesitic lavas. Major continental basalt plateaus formed in this way are found in South Africa (Karroo), South America (Parana), and India (Deccan), to name a few of the larger, better known, examples. The rocks of these plateaus provide us with one of the more direct ways of studying the composition of the earth's mantle, from which they are derived by partial melting, and allow us to examine the many complex processes which lead to the formation and growth of the earth's crust.

The Columbia River Basalt

The Columbia Plateau was formed by basalt that erupted from fissures during an 11-million-year period in the Miocene Epoch (between 17 million and 6 million years ago) (Fig. 1) (*4*). More than 95 percent of the enormous volume of basalt accumulated in the first 3.5 million years (Fig. 2) and covers an area of approximately 200,000 km^2 with an average thickness of more than 1 km; this

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area (Fig. 3) includes most of eastern Washington, a large part of northern Oregon, and significant parts of west central Idaho—a total area larger than the state of Washington. Other continental flood basalt provinces are even larger. The Columbia River basalts make up one of the youngest basalt plateau provinces, and although they are unusually well-preserved from weathering and erosion by a semiarid climate, they are deeply dissected by the steep-walled canyons of the great rivers of the Columbia-Snake system. The accessibility and freshness of the Columbia River basalts make them more amenable to detailed study than many of the larger, but older, basalt plateaus in more remote parts of the world, or their ocean floor equivalents.

Like other continental flood basalt provinces, the Columbia River Basalt Group was long regarded as a monotonous sequence of indistinguishable basalt flows. The development of rapid, precise techniques for the analysis of major and trace elements in rocks has changed this view. It is now technically and economically feasible to analyze many samples from a group of flows and to make the analyses available rapidly enough for field geologists to apply them directly as they map. Most Columbia River basalt flows or small groups of flows may now be identified by their chemical composition (*5*) (Fig. 4). Furthermore, a fluxgate magnetometer small enough to be carried on the field geologist's belt permits the magnetic polarity of each flow to be determined in the field. We know that the earth's magnetic field reverses itself periodically. Such magnetic reversals, and the striped magnetic patterns imprinted on the ocean crust parallel to and mirrored on either side of the ocean ridge-rift systems, provided one of the vital clues to our understanding of the creation of new oceanic crust by plate tectonics (*6*). In a vertical sequence of horizontal basalt flows accumulated over a period of 11 million years, we would therefore expect, and indeed find, many such magnetic reversals. The magnetostratigraphic rock units bracketed by these reversals (*7*) have been mapped (Fig. 1) and provide an unusually precise time correlation across the Columbia Plateau.

Together with the older arts of field mapping and microscope petrography, the new techniques of rapid analysis and magnetic polarity have established a detailed stratigraphic succession of the Columbia River Basalt Group (Fig. 1) (*8*). With a comprehensive stratigraphic succession established, it has been possible to clarify the physical and chemical evolution of the basalt magma during the 11 million years of volcanic activity, to correlate individual flows with their feeder dikes (fissures filled with solidified lava), to trace the flows back to their source, and to reconstruct the magnitude of the eruptions.

Group	Subgroup	Formation	Member	Magnetic Polarity	K/Ar Dates
Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Lower Monumental	N	6 my
			Ice Harbor	N, R	8 my
			Buford	R	
			Elephant Mountain	N, T	
			Pomona	R	12 my
			Esquatzel	N	
			Weissenfels Ridge	N	
			Asotin	N	
			Wilbur Creek	N	
			Umatilla	N	13.5 my
		Wanapum Basalt	Priest Rapids	R_3	
			Roza	T, R_3	
			Frenchman Springs	N_2	
		Grande Ronde Basalt	Eckler Mountain	N_2	14.5 my
				N_2	
		Picture Gorge Basalt (R_2)		R_2	
		Picture Gorge Basalt (N_1)		N_1	
				R_1	16.5 my
		Imnaha Basalt		T	
				N_0	
				R_0?	17.0 my

Fig. 1. Stratigraphic succession of the Columbia River Basalt Group (*4, 8*). The Picture Gorge Basalt is limited to the John Day Basin in the south central part of the province and was fed by its own dike swarm (Fig. 3). *N*, normal magnetic polarity; *R*, reversed magnetic polarity; *T*, transitional magnetic polarity; and *my*, million years.

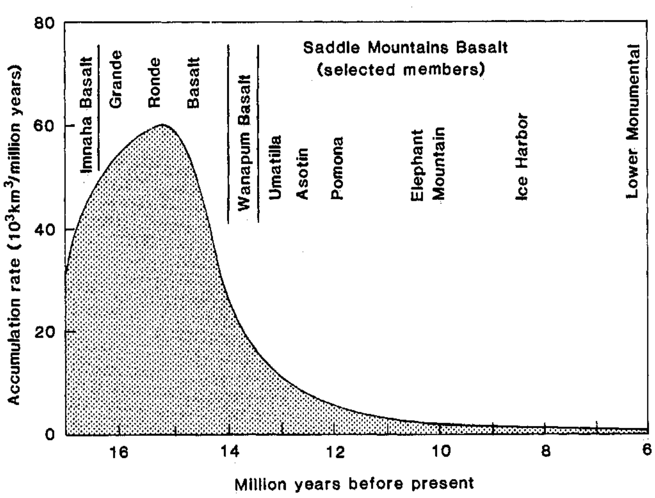


Fig. 2. Rate of basalt accumulation as a function of time.

History of the Volcanic Activity

The maximum observed thickness of the Columbia River basalts is 1500 meters, but basaltic rocks have been reported from drill cores as deep as 3000 m near the center of the plateau; the total thickness of the basalts, based on estimates of the greatest known thickness for each formation, is more than 2500 m. The Columbia River basalts fill a shallow basin; they are thickest at the center (Pasco Basin) and wedge out toward the margin of the basin (*8*). Rough calculations imply a total basalt volume of more than 200,000 km^3, and the number of flows ultimately identified on the plateau will probably be between 120 and 150. Individual flows range in thickness up to 120 m, with an average thickness of 15 to 30 m, and their areal extent varies from small spatter cones at source vents to major flows that cover a significant part of the Columbia Plateau, with volumes as large as 700 km^3. The flows were erupted from north-northwest to south-southeast fissures concentrated in the southeast part of the plateau, where dikes cut through both older lava flows and the surrounding prebasaltic rocks (*3*, *9*).

Volcanic activity began 16.9 ± 0.03 million years ago (*4*) at the southeastern extremity of the province, where the Snake River now separates Oregon and Idaho (Fig. 3). There, Imnaha Basalt lava (Fig. 1), containing large crystals of olivine, plagioclase feldspar, and occasionally clinopyroxene, poured from the fissures and filled two separate basins, which lie to the north and to the south of the Seven Devils–Wallowa Mountains divide. Some of the last Imnaha Basalt flows moved farther north into the present Clearwater drainage near Lewiston (Fig. 3), but they probably never reached the central part of the Columbia Plateau. The lava filled an older, deeply dissected surface that drained by way of a series of deep valleys to the west or southwest from the high ground of the still-rising Idaho granite batholith in the east.

There were 20 to 25 eruptions of Imnaha Basalt during a single magnetic polarity epoch lasting an estimated 500,000 years, or approximately one eruption every 20,000 years. During the transition from normal to reversed magnetic polarity about 16.5 million years ago, the nature of the erupting magma changed (Fig. 1). The later Grande Ronde Basalt is almost totally lacking in large crystals (phenocrysts) and is more siliceous than is the earlier Imnaha Basalt. With only minor compositional changes, the Grande Ronde Basalt poured out for the next 2 million years (Fig. 1), a period during which three more magnetic polarity reversals occurred (*8*). The center of activity had moved north to the present junction of the states of Oregon, Washington, and Idaho, and well over 60 flows were erupted at a greater average rate than is found either before or after this period; major eruptions occurred at the rate of one every 10,000 years at the peak of activity (Fig. 2). The Grande Ronde Basalt flooded virtually the whole Columbia Plateau, and some of its flows passed through the rising Cascade Range to reach the Pacific coast. The Grande Ronde constitutes more than 85 percent by volume of the whole Columbia River Basalt Group.

Then, about 14.5 million years ago, there was a hiatus in the volcanic activity, marking the end of the Grande Ronde Basalt period. Sediments were deposited on the lower ground to the west (Pasco Basin), and a prolonged period of weathering of the Grande Ronde Basalt occurred in the southeast. The lack of sediment deposition in the southeast reflects the gradual rise of this corner of the Columbia Plateau, which had probably begun well before the onset of volcanism. Later flows of Grande Ronde and younger basalts did not reach the higher topographic surface in significant volume in the southeast part of the plateau; although there are feeder dikes, which are associated with small volcanic cones

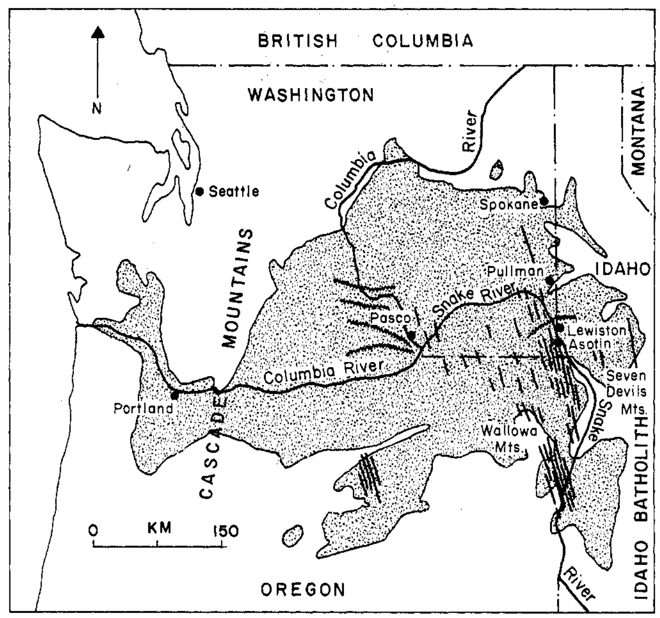


Fig. 3. Map of the area covered by the Columbia River basalts in the American Northwest. Heavy lines represent the orientation, approximate position, and concentration of the feeder dikes. Hatched lines represent the anticlinal ridges.

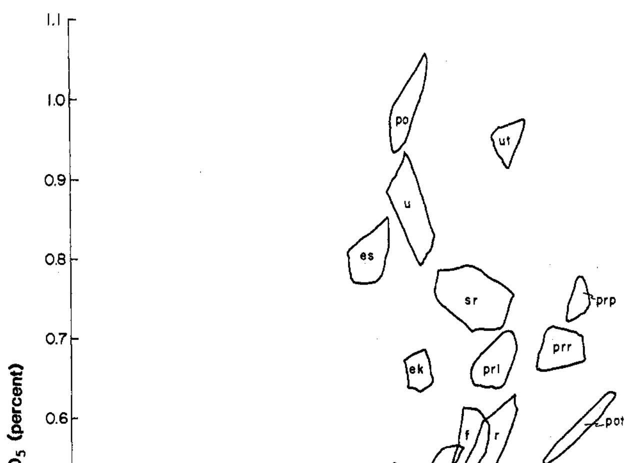
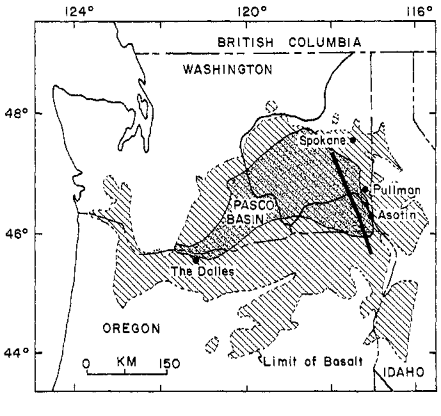


Fig. 4. Plot of percentages of P_2O_5 as a function of percentages of TiO_2 of various Columbia River Basalt flows (*5*). *RC*, Imnaha Basalt, Rock Creek type (88 analyses); *AB*, Imnaha Basalt, American Bar type (71); *PG*, Picture Gorge Basalt (40); *GR*, Grande Ronde Basalt (82). Wanapum and Saddle Mountains Basalt flows shown individually as follows: *po*, Powatka flow (21); *u*, Umatilla (20); *ut*, high TiO_2 Umatilla (5); *es*, Shumaker Creek (8); *sr*, Sopher Ridge (21); *ek*, Looking Glass (10); *prl*, Priest Rapids, Lolo type (25); *prr*, Priest Rapids, Rosalia type (10); *prp*, Priest Rapids, Pullman type (4); *pot*, Potlatch (5); *r*, Roza (10); *f*, Frenchman Springs (20); *l*, Lower Monumental (7); *wl*, Wiessenfels Ridge, Lewiston Orchards type (4); *ws*, Wiessenfels Ridge, Slippery Creek type (7); *em*, Elephant Mountain (22); *w*, Wilbur Creek (15); *cf*, Cricket Flat (8); *er*, Robinette Mountain (4); *ed*, Dodge (18); *la*, Lapwai (11); *gv*, Grangeville (12); *p*, Pomona (10); *b*, Buford (9); *cc*, Icicle Creek (5); and *fc*, Feary Creek (6).



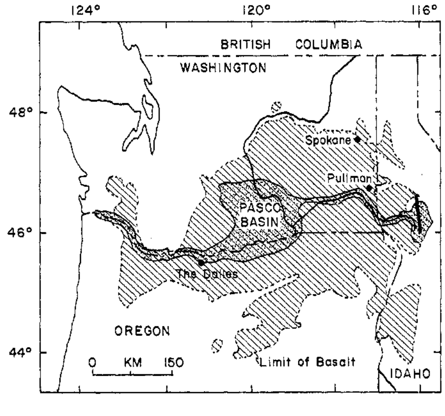


Fig. 5 (left). Areal extent of the Roza flow and its feeder dike system (heavy line) (*2, 3, 8*). Fig. 6 (right) Areal extent of the Pomona flow and its feeder dike system (heavy line) (*8, 12*).

in a linear system, the bulk of the lava poured out farther north or west where the fissures intersected a lower land surface.

The hiatus in activity was followed by the eruption of flows of Wanapum Basalt (Fig. 1). Relatively few flows (9 to 12) erupted, but many were of exceptionally large volume and are compositionally distinct both from each other and from the flows of Grande Ronde Basalt. These great Wanapum Basalt flows are among the best known on the plateau, and one, the Roza flow, is described in detail below.

Eruption of the Wanapum Basalt represents a significant decrease in the rate that magma reached the surface (Fig. 2). A further decline in activity is seen in the final phase of the Columbia River basalt activity, the eruption of the Saddle Mountains Basalt (Fig. 1). Although its extrusion lasted for more than 7.5 million years (13.5 million to 6 million years ago), the Saddle Mountains Basalt (*8*) forms less than 1 percent of the total volume of the Columbia River basalt (Fig. 2), and many small, compositionally divergent flows were erupted at relatively long intervals. The progressive deformation and erosion of the Columbia Plateau, although probably no more rapid at this time than earlier, is more easily seen because of the greater length of time between eruptions (*10*). Most Saddle Mountains Basalt flows are clearly unconformable on older flows, typically filling erosional valleys or structural basins. Although one group (Ice Harbor Member) was erupted near the center of the plateau, most were erupted near the eastern margin. The tendency of the Saddle Mountains Basalt flows to follow, fill, and often block the river valleys and canyons resulted in the formation of lakes and subsequently the production of pillow-palagonite complexes (altered basaltic glass), which formed when a flow plunged into and was chilled by the water. The lava was more dense than the unconsolidated sediments at the bottom of the lakes and often burrowed beneath the sediment to produce lava-sediment mixtures (*11, 12*). One Saddle Mountains Basalt flow, the Pomona flow, is described below.

The Roza Flow

The Roza (*2, 3*) is perhaps the best known flow on the Columbia Plateau. Well exposed near the surface across about 40,000 km^2 of the plateau (Fig. 5), it is easily recognized by its large, regularly distributed plagioclase phenocrysts. It is usually composed of two separate cooling units that probably erupted within a few hundred years of each other, with a total volume of about 1500 km^3. The flow was erupted from a series of closely spaced fissures lying in a belt about 5 km wide and 200 km long and oriented in a north-northwest to south-southeast direction near the east side of the plateau (Fig. 5). In this zone some 20 vents or vent areas are indicated by the presence of pumice, some cinders, and spatter or glassy fragments which are highly oxidized and often welded together because they were still hot and partly molten when they landed. Some vents form visible cones today, like Big Butte in the southeast corner of Washington. More often, the smaller vents were covered by later flows and are now exposed only by the accidents or erosion or road building.

The Roza flow erupted on ground that had tilted gently to the west since the previous eruption, so that the lava flowed but a few miles to the east, failing to reach the sites of Asotin and Pullman (Fig. 5). Downslope to the west, however, it flowed for more than 300 km across the Pasco Basin to the Cascades, and along the Columbia River Gorge as far as The Dalles (Fig. 5). Assuming (*2*) that most of the lava erupted from a 100-km length of the linear vent system and that each cooling unit had a volume of about 700 km^3, and using the known temperature and viscosity of such a lava, we can calculate that the flow moved over 300 km in just a few days at an average rate of about 5 km per hour. The Roza flow is approximately 30 m thick across large parts of the central plateau. Where the lava plunged into lakes in the Pasco area, almost pure glass formed, devoid of crystals other than intratelluric plagioclase phenocrysts, suggesting that the time between eruption and arrival of the flow at the lakeshore 150 km to the west was so short that little cooling and associated crystallization occurred (*2*).

The enormity of this event is hard to visualize. A lava front about 30 m high, over 100 km wide, and at a temperature of 1100°C, advanced at an average rate of 5 km per hour. The lava poured from the fissures at the rate of 1 km^3 per kilometer of fissure per day for about 7 days, an eruptive rate that is orders of magnitude higher than that calculated for recent activity on the Hawaiian volcanoes of Mauna Loa and Kilauea. Over the larger time span of some millions of years, however, the average rate of magma production appears similar to that of the Hawaiian volcanic center or the Iceland ridge-rift system (*2, 3*).

The Pomona Flow

A member of the Saddle Mountains Basalt Formation, the Pomona flow (*8, 12*) was erupted about 12 million years ago from a fissure on the most easterly limit of the province in north central Idaho (Fig. 6). It is easily identified both chemically and petrographically, containing numerous small phenocrysts of plagioclase, clinopyroxene, and olivine. The lava pouring from the fissure filled a local structural basin to the south, then flowed westward down the channel of the proto–Clearwater River. Large and small remnants of the flow plastered along the walls of the present Snake River canyon between Asotin and the Pasco Basin testify to its having followed and filled an earlier canyon, similar to the present one.

On reaching the Pasco Basin, more than 200 km from its feeder dike, the Pomona flow filled the river canyon and spread out over the basin floor (Fig. 6). It then continued down an ancestral Columbia River near the location of the present Columbia Gorge. A flow with the same chemical and mineralogical composition, the same magnetic polarity, and in the same apparent stratigraphic position relative to other Columbia River basalt flows is present west of Portland (*13*). Now that traces of the Pomona flow have been found in the Columbia Gorge (*14*), there can be little doubt that this same flow traveled substantially more than 550 km from north-central Idaho to the Pacific coast. It is probable that the deep-sided canyons would have created an effect not unlike a lava tunnel, in which the heated walls allow the molten lava to pour between them with negligible loss of heat. The alternative explanation, that eruption of identical basalt occurred at the same time on two sides of the active andesitic volcanoes of the Cascade Range, is much less credible (*13*).

Tectonic Framework for the Columbia River Basalt Eruption

What combination of tectonic events could have triggered this massive outpouring of basalt over the Columbia Plateau? Evolution of this part of the western American Cordilleran is still poorly understood. We know that in late Precambrian and early Paleozoic time (700 million to 400 million years ago) the western margin of the North American continent ran close to the present western border of Idaho and that crustal blocks farther west of this line, such as the Permian-Triassic rocks of the Blue Mountain Province, the rocks of the northern Cascades, and others farther west, are exotic, having moved into their present positions after their formation farther south (*15*). There is some geophysical evidence to suggest that a narrow wedge-shaped area lying just north of the Blue Mountains between these exotic blocks is underlain by oceanic, not continental, crust. It may be more than a coincidence that the main focus of the Columbia River basalt eruption lies near the apex of that wedge close to the ancient margin of the continent.

The Columbia River basalt was erupted between two active ridges. On the west the Cascade Mountains were rising by a combination of volcanic activity and upwarping. On the east the low-density granitic rocks of the Idaho batholith continued to rise along the old margin of the North American continent. In between, the ground over which the basalt flowed was tilted from east to west (*10*). Throughout the 11 million years of volcanic activity, this region was subjected to east-west tension and north-south compression, as evidenced by the north-south dike system and the east-west anticlinal ridges (Fig. 3). It is probable that the east-west tension was the cause of a decrease in pressure at depth and of the partial melting of the upper mantle in this region.

Along the southern and southwestern margins of the Columbia Plateau and farther southwest in Oregon, horizontal movement along the vertical northwest-southeast and northeast-southwest fault planes with clockwise rotation of the intervening crustal blocks is well documented (*16*) and could have resulted from a similar stress regime. The overriding of the East Pacific ridge-rift system by the North American continental plate in the early Miocene period and the creation of a "soft margin" to the North American continent, heated by the subduction of recently formed and still hot ocean crust as suggested by Atwater (*17*), is a likely means of developing of such a stress regime.

Origin and Evolution of the Columbia River Basalts

The relatively large silica content and small magnesium/iron ratio of continental flood basalt, compared to ocean ridge basalt, has often been assumed to indicate contamination of the rising lava with silica-rich and potassium-rich continental crust. The rather small $^{87}Sr/^{86}Sr$ ratios (which will increase when older continental crust is mixed with basalt lava) of the Columbia River basalts and the failure of such major elements as silicon and potassium to vary sympathetically with an increase in the strontium isotope ratio in the basalts (with the possible exception of the very small volumes of Saddle Mountains Basalt) (*18*) makes it unlikely that crustal contamination has played a significant role in their origin. The high rate of eruption and great length of the fissure systems for each flow also suggest that crystal fractionation (removal of early crystals from residual liquids) in large chambers just below the surface is not the principal mechanism that created the compositional differences between flows. Nor is there any obvious pattern of compositional change with time.

Alternative mechanisms to account for the origin of the Columbia River basalts and the compositional differences between the flows include variation in the composition of the mantle source for each batch of lava erupted, different degrees of partial melting for one or more source compositions, and crystal fractionation at some depth well below the surface. Theoretically, each of these possible mechanisms can be tested by the relative behavior of various chemical elements. In practice, the exercise is complex, and despite the wealth of data now available for the whole Columbia River basalt event, no wholly satisfactory solution has yet been offered.

Some elements, referred to as the incompatible elements, are almost totally excluded from the crystalline structures of the early precipitating minerals; phosphorus, barium, zirconium, lanthanum, and thorium are examples. Incompatible elements are highly concentrated in melts formed by small degrees of partial melting and are progressively diluted as the degree of partial melting increases. Conversely, they are progressively concentrated in residual liquids as the early crystalline minerals are removed. Throughout both these processes the ratios between the various incompatible elements should not vary significantly. The ratios do show substantial variation in the Columbia River basalts, and this has led to the suggestion that each major basalt flow represents a separate partial melt of a heterogeneous mantle source.

A partial melt of normal mantle rock will inevitably have a high magnesium/iron ratio and high concentrations of such elements as nickel and chromium. Once the new liquid is removed from the still crystalline mantle residue, then the magnesium/iron ratio and abundances of nickel and chromium will be reduced rapidly by the precipitation of relatively small volumes of such minerals as olivine and pyroxene. A possible explanation, then, for the unusually low magnesium/iron ratio and low concentrations of nickel and chromium in the Columbia River basalts is that they have suffered considerable crystal fractionation of olivine and pyroxene at some depth. However, simple computer models, in which various proportions of observed or possible early mineral phases are removed from one basalt flow composition to produce another flow composition, fail to provide quantitative support for this concept. Furthermore, one would expect greater variation than is in fact observed in magnesium/iron ratios and nickel and chromium values, depending on how much and what type of crystal fractionation occurred. This has led to the suggestion that crystal fractionation is minimal and that the mantle source is an iron-rich pyroxenite (*19*). Unfortunately, all the evidence provided by samples of mantle material brought to the surface in volcanic eruptions implies that such iron-rich material is extremely scarce in the mantle. To solve this basic dilemma, it has recently been suggested that the primary magma forms large chambers at the base of the crust, where crystal fractionation removes large quantities of olivine, clinopyroxene, and plagioclase, while the magma is renewed by more primary liquid from below. Such a chamber would serve both to buffer the variation in the magnesium/iron ratios and concentrations of nickel and chromium and to reduce them substantially (*20*).

That many problems remain concerning the origin of the Columbia River basalts is certain. But the wealth of chemical and mineral data now available on these rocks has provided a clear picture of the development of this immense volcanic outburst. The tectonic events associated with the eruptions are well understood and must now be reconciled with the larger concepts of plate movement and the causes of magma generation at depth. We have learned that the variation in composition between flows resulted from processes at depth rather than processes at or just below the surface, and current evidence suggests that the larger chemical differences between oceanic and continental basalts may be more closely related to the thickness of the overlying crust than to crustal contamination. Studies may now focus on the relative merits of models that emphasize the partial melting at depth of a heterogeneous, iron-rich mantle source, and more complex models in which magma reservoirs at the base of the crust fractionate early refractory minerals but are periodically tapped by a volcanic eruption and refilled by more partial melt from below.

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Variation of Influenza A, B, and C Viruses

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Although in this era we have witnessed the eradication of smallpox and can view the eradication of poliomyelitis and measles as a distinct possibility, the prevention of epidemic and pandemic influenza remains beyond our current capabilities. A number of factors may contribute to the problem of influenza control, but the major factor that has limited our ability to control the disease is the capacity of influenza viruses (*1, 2*) in nature to vary rapidly and undergo changes in antigenic structure that circumvent the protective effects of a patient's immune response. This variability of influenza viruses is in marked contrast to the antigenic properties of other viral agents, such as polio virus or measles virus, which appear to remain essentially unchanged. The situation with influenza viruses also differs from that of herpes or rhinoviruses which coexist as a number of variants in the population but do not undergo the rapid changes that are observed in influenza viruses.

The number of people contracting influenza can vary considerably from year to year. Although a pandemic of the severity observed in 1918 has not occurred in the last six decades, serologic evidence suggests that a new influenza virus strain may infect more than 50 percent of a population within a period of 2 years (*3*) and cause death in many compromised patients. For example, from 1968 to 1981 an estimated 150,000 people died of the effects of influenza virus infections in the United States alone (*4*). In addition to influenza, Reye's syndrome, a disease with a high mortality rate in children, has been associated with influenza viruses (*5*). Typically, this disease involves an inflammation of the brain and fatty degeneration of the liver.

Influenza viruses have long been known to cause disease in other animals besides humans. For example, fowl plague virus causes high mortality in chickens and is of great commercial sig-

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