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Edwin T. Hodge
(Major professor)

THE

HISTORY AND PETROGRAPHY

OF THE

BASALTS OF OREGON

By

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A Thesis

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basalt types of north central Oregon, the Cascade Range in the northern part of the state, as well as a few specimens taken from the western side of the Cascades as far south as Oakridge. The classification also includes specimens of the Ten Mile Basalt formation of the Coast Range and a few random specimens with definite localities collected by different workers previous to 1924.

REVIEW

of the

LITERATURE.

PART

I

Pre-Tertiary Basalts.

Paleozoic (general).

Diller and Kay (52)* state that some of the fine-grained effusive basaltic greenstones which lie between the Dothan and Galice formations in the Riddle Quadrangle may be of Paleozoic age. They (51) also say that some of the greenstones of the Grants Pass Quadrangle are compact like basalts and are of Paleozoic age. They place these basaltic rocks in no definite period of the Paleozoic.

Carboniferous.

Lindgren (49), 1902, states that Carboniferous lavas are found intercalated in sedimentary beds of the same age at Pleasant Valley and at Unity; also on the road to Clifford from Sumpter, on McCully Fork, a few miles from Sumpter, and in Quartz Gulch, on Olive Creek. These lavas are greatly altered greenstones, of massive and roughly schistose structure. They are so badly altered that the original character can hardly be ascertained.

Mesozoic Basalts.

Triassic lavas extending from North Powder to Eagle Creek along the foothills of the range have been described by Lindgren (49) in 1902. These lavas are made up of old basalts, andesites and tuffs containing in places small masses of limestones and shales. "Though greatly altered, they are as a rule not schistose, except in the central part of the Eagle Creek mountains. Fine-grained uralitic metabasalts were found in the

* *

*Reference numbers to bibliography.

Farley Hills. Near Copper Butte and the claims of the North American Copper Company dark-green or brownish amygdaloidal metabasalts and tuffs, often full of calcite nodules and veinlets of zeolites were collected. Similiar altered basalts, andesites, and rhyolites with their tuffs, were found at many places along Snake River below Pine Creek. At Sheep Rock mine, on East Eagle Creek, below the Triassic limestone, appears a volcanic breccia of metabasalt and other lavas, which also contains fragments of a granitic rock. A few miles farther up this breccia becomes highly schistose. Its original character is not apparent to the naked eye, but the microscope reveals it very plainly. The fragments of lava are pressed flat or lenticular, and secondary hornblende and chlorite suffuses the whole rock."

Jurassic Basalts.

Diller and Kay (32) in the Riddle Folio state that gabbroic rocks, of the Jurassic age make up a large area near Placer and Winona and in the vicinity of Sexton Mountain. The rocks, where unaltered, consist of about equal parts of angite and plagioclase in some areas while in other localities where the gabbro is coarser than usual the fabric is distinctly ophitic containing primary hornblende as the principal dark minerd. Most of the gabbros show considerable alterations; zoisite and kaolinite are derived from the plagioclases and calcite and titainte from the dark minerals. In a hornblende gabbro there is considerable chlorite and magnetite.

Cretaceous.

The geological age of the gabbroic intrusions of the Port Orford district (Diller 26) "is fixed approximately by its penetrating the Myrtle formation (Cretaceous) on the one-hand and being covered by the Arago (Eocene) formation on the other."

The normal gabbro forms the summit of Bald Mountain. It is composed almost entirely of plagioclase and pyroxene and has been greatly altered, yeilding, among other minerals, minute grains of epidote, but its characteristic twinning is still preserved. The prevailing texture is granitic and the grains of pyroxene and feldspar are for the most part irregular, although many of those of the feldspar are euhedral crystals giving to the rock a tendency toward an ophitic or porphyritic structure. It is composed brown or greenish hornblende with occasional traces of clear cores apparently of pyroxene. Numerous grains of magnetite or ilmenite are present.

Louderback (51), 1905, states that the metagabbros of the Riddle formation are of the Cretaceous age.

The basalts of the Port Orford Quadrangle occur in small areas. They are especially abundant in the northern portion and frequently form prominent ledges which rise above the general level.

The relative age of the basalt is the same as that of the gabbro, and they show that at the end of the Cretaceous there was vigorous volcanic activity in that region.

The basalts are granulitic or slightly porphyritic, with a finer texture than a granite. The feldspar is much altered and full of inclusions. The percentage of lime is remarkably high. One specimen from a ledge at the mouth of Sucker Creek shows a structure which is ophitic rather than granular. The long lath-shaped crystals of plagioclase are separated largely by chlorite resulting from the alteration of pyroxene.

Butler and Mitchell (7) in 1916, in a report on Curry County note the occurrence of a basalt of Cretaceous age at Horse-sign Butte, a dark-colored, fine grained, unaltered basalt composed of plagioclase and pyroxene and occurring as a stack probably connected with the gabbroic mass below.

Tertiary Basalts

Eocene.

J. S. Diller (27) in the Roseburg folio has described a Eocene diabase dike occurring a short distance north of Roseburg, "enclosing a small piece of Umpqua shale which along the contact is rendered glassy by the chilling influence of the shale"-----. "East of Oakland, as well as along Little River and the North Fork of the Umpqua, the diabase occurs clearly as a dike penetrating the Umpqua formation, and judging from these examples it is fair to conclude that it is generally younger than the oldest portion of the Umpqua formation, and has been erupted through it. The igneous products are found interstratified with the Upper Umpqua formation, and characteristic fossils occur intermingled with them, fixing the age of the diabase intrusion as within the Eocene."

The diabase is a dark, heavy, dense igneous rock, composed principally of augite and plagioclase of the lime-soda variety, so arranged that the grains of augite occupy the angular spaces between the crystals of feldspar, giving the rock its characteristic ophitic structure. Olivine is frequently present. Near its contact with other rock, where it cooled rapidly, the diabase contains much amorphous matter, which is occasionally glassy.

The Eocene basalts of the Roseburg Quadrangle are described by Diller (27). They cover approximately 150 square miles in that region. The basalts differ from the andesite and rhyolite flows in their immediate vicinity by their characteristic dark color, somewhat smaller percentage of silica,---their greater specific gravity, and larger percentage of metals, especially iron. Some of the flows are rich in olivine; others in pyroxene, a portion of which is hypersthene. Although phenocrysts are not common, those of feldspar are more frequently seen than those of either olivine or pyroxene.

There are no well-preserved cinder cones or volcanic piles to mark the orifices from which the lavas escaped because the region has suffered too much erosion to permit their preservation.

Diller (21) in the Coos Bay Folio, states that "along the eastern portion of the Quadrangle in Range 12, extending from the head of Kentucky Slough to the Middle Fork of the Coquille, there are four igneous masses which are generally basaltic in character."

North of Coos River are half a dozen apparently separate outcrops, which are in all probability connected beneath the adjacent sandstone. The basalt is well exposed about the head of Kentucky and Willard Sloughs and along Coos River below the forks, but the intermediate divides are capped by sandstone belonging to the Pulaski formation of Eocene age. Where the relation of the Pulaski formation and the basalt is well exposed, the sheets of basalt either lie conformally between the beds of Pulaski sandstone or break through them. It is evident from these facts that the eruption of basalt occurred during the Pulaski Epoch.

Southeast of Coquille, the basalt forms prominent hills around the head of Glen Aiken Creek, and Sugar Loaf Mountain east of Myrtle Point, is of highly altered basalts perhaps older than the Pulaski.

All of the basalts are composed essentially of plagioclase (anorthite or labradorite) and augite, with more or less olivine and magnetite and differs chiefly in crystallization and structure. In some the olivine is replaced by serpentine, oxide of iron, and carbonate of lime, and augite chiefly by chlorite.

In places the basalt is rather coarse-grained, the grains of feldspar have crystallographic boundaries and the augite occupies the irregular spaces between them giving rise to the ophitic structure which characterises diabase, but generally the structure when wholly crystalline is granulitic. Generally, the rock is holocrystalline, but in places some of the material is amorphous and the rock has the appearance of a lava which flowed out upon the surface.

Smith (75), 1917, states that the basaltic dikes of the Eugene Quadrangle are of Eocene age.

Eocene basalts of the Clarno formation of North Central Oregon have been reported by Merriam (56), 1901, Calkins (9), 1902, and by Collier (17) in 1916, and numerous other writers, all of whom have done nothing more than merely state that the Clarno formation is composed of basalts, andesites, rhyolites and tuffs.

Miocene Basalts.

Columbia River Basalt Formation.

The Columbia River Lavas were first named by I. C. Russell (70) in 1893 to designate the large volcanic series in eastern Oregon. He included rhylites, andesites and basalts all in the one major grouping making no effort to distinguish between the older and younger flows of the tertiary. Later in 1897 (71), he correlated the eastern Oregon basalts with the Yakima basalt of southeastern Washington, thus separating the acid extrusives of the Columbia River Lavas from the more basic basalts. Merriam (58) in 1901, uses the term "Yakima Basalt" pertaining to that portion of the Columbia River Lavas over-lying the John Day formation near John Day, Oregon and was substantiated by Collier (17) in 1916.

Russell, (71a) in 1901, correlates the "Snake River Lavas" with the "Columbia River Lavas" of eastern Oregon, thereby, connecting definitely the lavas of the three states, Oregon, Washington and Idaho.

Lindgren (49) in 1902, correlates the basalt of the Blue Mountains as Columbia River formation but restricts the term to the basaltic lavas of the Miocene to distinguish between different kinds of lavas of the Pliocene and Miocene.

The basalts of the Deschutes Plains have been separated from the underlying "Columbia River Lavas" since Condon (18) in 1879 separated the basalts which he says originated from the Blue Mountains and those originating in the Cascades. He was followed in this separation by Diller (25) in 1884; Russell (68) in 1905, and by Hodge (46) 1928, until at the present time the term "Columbia River Lavas" as given by Russell has changed to "The Columbia River basalt" used to include only that series of basalts which have their type occurrence along the Columbia River and which lie unconformably on the Oligocene tuffs of the John Day formation or on older formations.

The Character of the Columbia River Basalt Formation.

The first attempt to describe the great Columbia River Basalt Formation was made by J. Ball (1) in 1835. He remarked upon their resemblance to the Giants Causeway stating that they showed very strong marks of ignition. Dana (19), 1849, noted their superficial resemblance to Mexican flows of basalt.

Le Conte (48) in 1874, described the 'great lava flood' as a universal flood overlying the original face of the country several thousand feet thick and covering approximately 300,000 square miles. The flood being made up of a large number of individual flows as high as 10 or 12 that could be counted above the conglomerate on the south side of the Columbia River.

Merriam (55) counted as high as 23 separate and distinct flows in the Picture Gorge locality. The individual flows of basalts interbedded with insignificant amounts of basaltic tuff Merriam and Sinclair (57); Bretz (5); A. J. Collier (16), (17); Lindgren, (48) however, states that, "in a few places water laid clays and sands with local lignites are intercalated doubtless accumulated by rivers during lulls in eruption; tuffs are absent.". "These flows covered vast areas in eastern Oregon completely burying older topography or surrounding it as in the case of the Blue Mountains, which were left as an island in a great sea of basalt" (Lindgren (49)). These flows "completely blotted out the angular summits of a large range of mountains now exposed in the Snake River gorge (Swartley (76)), "forming the lava plateaus of eastern Oregon and capping many hills, extending down into valleys, the lavas poured out on an irregular surface and caused late tertiary lakes, (U. S. Grant and C. H. Cady (40)).

The individual flows of the formation consist of "high, black rocks 1' to 5' in diameter, composed of blocks of concave form, set in each other, till they are raised to a great height" - J. Ball (1).

I. C. Russell (69) states that "the horizontal joints cut vertical columns and, in some cases, may be traced for several miles. Large vertical columns when weathered occasionally show that they are composed of small horizontal columns or prisms, which radiate from a confusedly central core. The joints which bound the large vertical columns furnished the cooling surfaces for the rocks they enclose. The bases or ends of the radiating columns are frequently revealed on the surfaces of the slightly weathered vertical columns by a network of lines resembling shrinkage cracks.

F. C. Calkins (9), however, states that "the structural features of the basalts as observed in the field are not especially remarkable. The development of columnar structure in both dike and flows, is general the size and perfection of the columns increasing with the thickness of the mass in which they occur. The upper portions of the flows have the usual vesicular character, and the slaggy and ropey surfaces have been especially well-preserved in certain cases where the overlying layer has been tuff rather than of lava."

Pardee and Hewitt, (61), describe a thin veneer of Columbia basalt at Coyote Point, E. and N. of Haines, composed of thin plates or sheets 1/8" to 1' to 2' in thickness dipping 20° to 25° N.W.

A characteristic feature mentioned by all writers is the relative crystallinity of the basalt with respect to its position in the flow, the central portions well-crystallized with the two margins relatively glassy or fine-grained in respect to it.

The Thickness of the Columbia River Basalt Formation.

The greatest thickness of the formation is exposed in the northeastern and southeastern portions of the state. In the very northeastern corner of the state along 46° and 46° 30' bounded by 117° longitude, a thickness of 2000' to 4000', varying according to the old surfaces, has been mapped by Lindgren (48). Farther south in the Seven Devils Canyon adjacent to the Blue Mountains 5000' is exposed, I. C. Russell (69), O. D. Reid (64), and A. M. Swartley (76). The basalt gradually thins to the south, since from the Owyhee River to Ontario, the total thickness is only 1300' (Owyhee Basalt correlated by Renick (65) to the Col.). J. Le Conte (46) gives a thickness of 700' undoubtedly taken farther south.

Westward along the south central portion of the state in Lake and Harney counties Waring (78,79) has given the thickness of the basalt as an average of 1000'. But Smith (72) has placed the 4000' eastern scarp of Steen's Mountain as Columbia basalt and is substantiated in his correlation by E. Waters (80)

In Central Oregon proper, the basalt reaches a maximum of 2900'. In generalized section of the John Day region, A. J. Collier (16), has measured a section at both Picture Gorge and Flat Creek localities. Thinning out to the south and east to its 1000' level in the lower canyon of the Powder River (U. S. Grant and C. H. Cady 40) and to as low as 15' on Coyote Point E. and N. of Haines. This is the thinnest covering of Columbia River Basalt in any area mentioned and marks the northern boundary of the formation in that section.

West from Picture Gorge the formation follows the John Day River to Twickenham from which place it has been eroded from the underlying formations. It reappears north of Fossil a short distance where Hodge (43) in his map of north central Oregon shows 200' of basalt above Fossil and maximum thickness of 1600' farther west to where the formation passes under the Cascade series. There is 700' exposed at South Junction lying on Clarno Formation, a maximum thickness of 1500' exposed down the Deschutes and John Day rivers to their mouths where only 1000' is exposed.

Eastward from the mouth of the John Day, the basalt exposed decreases on the Oregon side until at Pine Creek, near Milton-Freewater, the

Columbia flooring the valley is only 20' high, J. Bretz (5).

Westward from the mouth of the Deschutes river, the basalt is believed to be 3000' thick with 1000' exposed at the Dalles, E. Bergeshiemer (41), and 2000' in a complete section at Bonneville Chaney (13) 1300' is exposed six miles south of Bonneville up Eagle Creek and is mapped by Barnes and Butler (2) who have also mapped 500' at Taylorville Falls on the Columbia River. There is an undetermined thickness of basalt on Mt. Tabor, Portland, which according to Diller (24) is a remnant of the extensive flow. Diller traces the basalt as far north and west as Rainier, Oregon. Williams and Parks (88) have mapped 700' of Columbia River basalt in northern Columbia County indicating that the formation could have extended farther west even than Diller's mapping.

South of Portland there is 600' of the formation exposed at Oregon City (Diller 24), and east of Oregon City, Barnes and Butler (2), along R. 6 E. between 44° 30' & 45 have mapped 900' of Columbia River basalt on the North Fork of Bull Run River, 300' on Sandy River and 1900' on the Clackamas River.

South from Oregon City, Hodge (42), has stated that "the Columbia River basalt formation reappears just west of the Cascade divide and forms a maturely dissected plateau extending to the Willamette Valley. It holds the subsequent Willamette River in place on the soft eastward dipping Oligocene tuffs." Hodge (42), also reports the formation at 4800' on the tributaries of the Santiam. Smith (72) reports Columbia River basalt at 1200' at Cascadia on South Fork Santiam.

Diller (24) reports tertiary basalts, presumably Columbia River basalt, since he does not differentiate them from ones mapped farther north, as far south as the State line. These basalts are covered by Cascade series of andesites and no thickness is given. But, J. D. Pardee (60) gives 500' of basalt, comparable "to the tertiary volcanics that compose the Middle and Southern Cascade series", at Lake Creek near Eagle Point, Oregon. Howard A. Powers (62) further substantiates this statement by placing the basalts along Bear Creek in southern Oregon in the tertiary volcanic system of the Cascades.

The Topography.

The topography of the greater portion of eastern Oregon is the result of the denudation of that area by the great number of basalt flows of the Columbia River basalts which, according to Collier (16), "over much of this region the formation has been left approximately horizontal, and in such cases is universally level enough for plowland, while the streams often flow in narrow canyons with rim rocks exposed in their walls. In many cases where the rim rock has been folded, faulted or otherwise disturbed by subsequent mountain building process, it has been removed by erosion and the underlying and often softer formations are exposed. In such cases the topography is more friable."

Hodge (43) gives a very good description of the topography, structure and the physiography all resulting from several erosional periods or "stages" and calls the resulting topography the 'Shaniko topography' to differentiate between the erosional topography of the Columbia River basalt formation, the Madras formation and the older, or "Ashwood topography."

"The Shaniko topography as it exists today is the direct result of uplift, followed by erosion controlled by structure. Compressive stresses apparently from the northwest and southeast produced N.E. and S.W. folding. Where these folds intersected with pre-existing N.W. and S.E. structures quaquaversal doming was produced and where folding did not relieve the strain there was faulting and fracturing."

"North of Mutton Mountain, Antelope Creek and the south line of Township 6, the great central Oregon Columbia basalt plateau extends indefinitely northward. This is a perfect plateau. Standing at any one point within it one sees an almost perfectly flat surface stretching off to a horizontal skyline. At most it is very gently undulating. Although the surface seems almost flat careful measurements show that it slopes with the structure gently to the north and that across it are several gentle rolls almost indiscernible to the eye. For instance, a gentle roll extends E - W across Buck Hollow and Thirty-mile Creek. Other interruptions are Gordon Ridge and Sloan Hill and Tygh Ridge. The latter is a great monoclinal fold partly faulted on one side."

"This plateau may be divided into three parts. First, a large undisturbed, interstream upland. Second, gentle erosional sags resulting from gentle slopes to the canyons, which are the remnants of the shallow gentle-walled valleys of streams that once meandered over its surface. Third, the deep, precipitous canyons due to comparatively recent dissection."

"There are many examples of minor structural control of the topography. Thus, Squaw Creek, a branch of Rock Creek north of Quinton, is developed on an anticlinal fold. Thirtymile Creek and Buck Creek are developed on a synclinal fold. The Deschutes River for long streches at several parts of its course is on anticlinal folds. There are numerous cases of streams, the courses of which were determined by dip-slopes of the plateau or upon limbs of folds within the plateau. Examples of such consequent streams are: The lower portion of the John Day and Deschutes Rivers, Bakeoven, Buck Creek and Hinn."

"There are some streams which flow in the opposite direction to the dip, as for example, Ward Creek and Chapman Creek."

"The stream types above mentioned are those that have not yet succeeded in cutting through the Columbia basalt formation. There are others that have developed subsequently on the Ashwood Topography at the contact with the Shaniko Topography, especially where the contact exposes a soft formation, such as Skookum Creek; or between Shaniko and Madras Topography as Chenowith Creek. Despite these special features the general drainage pattern on the surface is dendritic."

"The stream pattern and distribution considered as a whole has a number of peculiarities. Thus, the Deschutes River received only small and generally waterless tributaries from its mouth to Farghar. In every case the tributaries of the Deschutes are lonesome streams with very few branches. In contrast the tributaries of the John Day River have numerous branches and have developed an almost perfect drainage system.

The John Day River like the Deschutes has no tributaries on the west side, or only minor ones, as far south as Pine Hollow. The result of this is that the plateau between Fifteen Mile Creek and the Deschutes, and between the Deschutes and John Day Rivers is a flat, poorly drained upland in an extreme state of youth, while the plateau east of the John Day River is well-drained and in late youth. Since the Shaniko surface in all parts is one age, it is evident that the part east of the John Day River has for a long time received a much greater rainfall."

"The tributaries to these master streams have gash-like, V-shaped valleys which, considering the size of the streams have great depths. A characteristic of these tributary canyons is that the slopes facing north have grass and soil while those facing south are barren and rocky. This is also characteristic of the main river spurs and the upland hills. The rains come from the southwest and wash away all soil from the steep north slopes."

The Structure.

The general character of the structures exhibited by the Columbia River basalt formation was included in Dr. Hodge's article on the topographic effects.

Collier (17) states that folding of the Columbia River basalt formation followed the deposition of the late Miocene Mascall formation.

The most prominent flexures of the Columbia River basalt formation are the Ortley and Bingen anticlines which cross the Columbia River near the towns from which they take their names. These anticlines have been described by various writers including I. A. Williams (84), Bretz (4) and E. T. Hodge, who has recently presented a paper to the Geological Society of America which deals with these flexures. According to Bretz (4), the Columbia River for 125 miles upstream from The Dalles, and a few miles downstream, flows in the bottom of a broad syncline and the group of rapids at Fallbridge to The Dalles are located on a minor upwarp of this floor.

Collier (16) describes a structural depression in the vicinity of Condon which has also been mapped by Hodge. Collier (17) describes the formation near Dayville stating that "the Columbia River basalt formation dips southward 16° a few miles north of Dayville and south of Dayville it rises vertically, thus forming a narrow syncline extending east and west for a long distance.

There are many minor flexures, too numerous to mention in this paper, which have been mentioned by various authors.

Faulting.

The Columbia formation is faulted locally in many localities but the major faulting is most apparent along the Columbia River where a great system of mosaic fault blocks has been described by E. T. Hodge in a recent, as yet unpublished, paper read before the G. S. A.

The great horst and graben features of faulting in southeastern Oregon have been well described by Smith (72), Waring (78,79), Russell (69), G. K. Gilbert (38), A. Waters (80) and Fuller and Waters(36).

The Age.

Many different ages have been given the Columbia basalts by different writers. J. Le Conte (46), probably the first writer to definitely give an age to the basalts of the Columbia River Gorge, placed the age of the basalts underlying the Cascades Mountains as late Miocene on the basis of Eocene oak and conifer leaves underlying the basalts.

I. C. Russell (70) before the separation of the Columbia River lavas gave their age as tertiary, but with the separation of the formation into more definite groups the age has been determined as Miocene by Lindgren (47), Collier (17); Early Miocene by Merriam and Sinclair (58) who based their determination by fossil fauna found in the Mascall which conformably overlies the Columbia; Middle Miocene by Collier (16), on the basis of fauna found in the Mascall and E. T. Hodge (42), W. D. Smith (72), Bailey Willis (87), and J. Coleman Renick (65) have given the age as Middle Miocene on strategraphical basis.

The Origin.

The most puzzling question connected with the Columbia River basalt flows is their origin. What could have been the prevailing mode of extravasion of such a large body of molten material that covered approximately 200,000 square miles of three western states? Three theories have been advanced by different writers.

Theory of fissure eruptions.

J. D. Dana (19) in 1849, was the first geologist to state that fissures were the dominant source of the Columbia River basalts. He states that "the eruption of these basalts and lavas had taken place from fissures throughout the country, --fissures which were more numerous near the volcanic peaks, but also intersected the whole region to the coast. They cut through the Tertiary rocks, and were also interstratified with them."

J. Le Conte (48) in 1874, in an article on "the great Lava Flood" attributed the origin of the great basaltic plain of eastern Oregon as being due to fissure eruption basing his argument on the absence of vesicles so common to ejected lavas, the lava being a solid mass, the 'boursouflee' condition so characteristic of volcanic action only noticeable on the uppermost part of flows.

No definite evidence of the prevailing mode of extravasion was given until J. C. Merriam (56) in 1902, found dikes penetrating the John Day beds in the vicinity of Turtle Cove.

Further evidence substantiated the theory of fissure eruption when Lindgren (42) in 1902, reported a large number of basalt dikes at Cornucopia and other places high upon the flanks of the Blue Mountains. "These dikes were in such a position relative to the flows that it is not to be doubted that the foci of the eruption was located at these places." Other localities in this region where dikes are located are; Bonanza Mine, Rye Valley to Mormon Basin, Simmons Mountain and Cornucopia Mine. A recent author, Goodspeed (39) in 1928 gives the mode of occurrence of a reaction porphyry dike at Cornucopia, Oregon, and states that in the Miocene, after elevation and erosion to maturity, vast floods of basaltic lavas from fissure eruptions covered the older rocks.

F. C. Calkins (10) in 1905, in a paper on the Yakima basalts, which he correlates with the Miocene series of Prof. Russell's Columbia lavas gives their origin as fissures because, first, their volume and extent are so enormous; second, a rarity of fragmental materials known as "tuffs", 'breccias' indicates a quite upwelling through fissures without the explosive action of craters; and third, an actual observation of fissures in the northern Cascades passing through sandstone underlying basalt.

E. T. Hodge (42) gives further evidence of the fissure type of eruption in using Mt. Multnomah; Ancient ancestor of the Three Sisters' as a fissure. He states, 'down the slopes of Mt. Multnomah and other fissures north and south, poured out great floods of basaltic lava.' He, later in the paper, makes the statement which leaves the impression that there was some explosive volcanic action accompanying the fissure

Fissure and Vent origin.

Several writers have not definitely assigned the basaltic lava to either vents or fissures but have placed them as originating, as a whole, from both.

Jacques W. Redway (63) in 1901, cites a large number of craters in the Deschutes plain 400 feet high and 200 feet in diameter and says that crater eruptions are sometimes the offspring of fissure eruptions no matter whether the latter are intrusive or extrusive. The weak point lies in the fact that his "craters" are probably the origin of the subsequent Pliocene or Pliestocene lavas which overlie the Columbia basalt in the Deschutes plain. He does state, however that the flows blocking and obliterating the Columbia and Snake Rivers originated from fissures.

W. D. Smith (72), 1927, "In view of such vents (local around Steen's Mountain) and the dikes seen in the eastern face of Steen's Mountain, we can be quite positive in our conclusion as to the formation of the great eastern Oregon lava flood. In the first place, what is known as the Snake River or Columbia lava is a composite of many floods; and second it came from many vents, some more or less local and circular, while others were lineal fissures.

E. T. Hodge (42) (as shown under 'fissure eruptions') also gives evidence as to crater eruption in combination with fissure.

Petrography of the Columbia River Basalts.

The petrographic descriptions found in the literature are too lengthy to be abstracted completely but a summary would show them to be typical basalts, massive, compact usually black in color with various tints of gray, green, brown and red mainly due to weathering, with a wide textural range from hypocrystalline to holocrystalline. The difference in specimens due mainly to structural differences. Difference in conditions of cooling which have naturally given rise to various degrees of crystallization, so that we have on the one hand, interstitial basalts with a large portion of glassy base, and on the other, holocrystalline rocks with typical ophitic or granulitic structure, Calkins (9). The central portions of the sheet being coarser grained than either exterior surface (Russell (71)).

The principal minerals are plagioclase, augite, olivine, iron and apatite with natrolite and analcite in the cavities (Calkins 9). But according to Lindgren (49) olivine may or may not be an important constituent.

"They may or may not contain olivine. The rock shows a moderate amount of glassy groundmass, occasionally, however, this glassy base almost disappears and then the rock is usually somewhat coarser, having the appearance of a diabasic rock. When veicular and massive flows alternate, the former are usually the more glassy varieties." Lindgren(49).

Localities from which olivine bearing basalts of this formation have been petrographically studied are: Mouth of Canyon at town of John Day, Lindgren, (49); Fisher's Landing, Mt. Tabor, Johnson Creek and Rocky Butte near Portland, N. H. Darton (20); specimens from central Oregon by Calkins (9); Wallowa Range, Swartley, (76); T. T. Hodge, (42) near head of Santiam; Glass Buttes, A. Waters (80); McKenzie River section, Ian Campbell (12). In southwestern Oregon by Winchell (86) at Grizzly Mountain and a sill or flow in Sec., 13 T. 38 N., R.2 W.

The olivine free Columbia basalts are relatively scarce, those localities reported are: Owyhee basalt, J. C. Renick (65), Waring (78) does not report olivine in his description of south central Oregon basalts, nor does Smith in basalts from Steen's Mountain, and Lindgren (49) in a specimen of unusually glassy basalt from north of Medical Springs.

In southwestern Oregon olivine free basalt is reported by Winchell (86) north of Ashland.

Economic values of the Columbia River basalt.

Lindgren (48); 1897, states that "the interbeds of clay and sand and gravel make ideal artesian water conditions" and reports a number of flowing wells in central eastern Oregon.

Another economic value of the formation is one reported by I. A. Williams and H. M. Parks (85) in 1923 where they show that the basalts of the Columbia River formation in Columbia Cty contain 10 to 15% of iron oxide and are the source of the limonitic "shot" soils of that locality.

The most extensive commercial use of the basalts is that for road metal at many places, standing among the very best materials obtainable for road construction, according to Diller (22) 1896, who also states "that owing to its somber color it is little used for building, excepting for foundations, and for this purpose it has a wide application."

The greatest economic value of the Columbia River basalt formation is the erosion of it and subsequent depositon of the material in the valley basins where it forms the fertile soils so common in northwestern Oregon. Diller (22) mentions the fact that the fertility of the great Willamette valley is largely due to the rich soil furnished by the alteration and disintegration of the lavas.

The great plains of eastern Oregon used as wheat lands are also composed of soil resulting from disintegration and decay of the underlying Columbia basalt, Collier (16,17).

Middle Miocene Basalts

Ten Mile Basalts.

Callaghan (11) in 1927, describes a formation of Middle Miocene age in the Heceta Head district which he names the Ten Mile basalt formation.

This basalt is of effusive origin and extends eastward from the coast to Klickitat Mountain, elevation 1800', and south to Cape Mountain and north to Yachats Mountain.

"Megascopically the formation is made up of two types of rock, dense basalt and basalt agglomerate occurring in nearly equal proportions, the agglomerate possibly predominating. Microscopically the basalt is of three types, basalt with labradorite, hawaiite or andesine basalt, and olivine diabase. The first two are dominant types and were found both with and without porphyritic texture. Otherwise they are dense and black on fresh surfaces but yellowish or brownish on weathering, sometimes turning almost white."

Upper Miocene Basalts.

The only basalts of Upper Miocene age recorded in the literature is the Blackjack formation of the lower Owyhee River district. This formation has been described by Bryan (7), 1929, who wrote on the geology and by Renick (64), 1930, in an extensive treaties on the petrography of that general region.

This formation covers approximately 25 square miles and originated from cones resting on the lava surface three miles northwest of Blackjack

Butte, and possibly from fissures also. It reaches a total thickness of 350' to 450' in the central portions and decreases in thickness eastward toward the Snake River and westward toward the lower Owyhee River. The flows apparently lie directly on the Owyhee (Columbia River) basalt at Hole-in-the-Ground, but in the bluff west of the Snake River 700' of sediments separate them.

The weathered outcrops generally have a rough, dark-brown surface, but some flows are red and the rock is usually vesicular. The Blackjack basalt generally has a banded texture both in the vesicular and the non-vesicular types. When such is the case of the lithology serves to identify it as a flow of Blackjack basalt. The bands which are rudely parallel with the top of the flow and are defined by the arrangement of the vesicles, where present, and in the case of the non-vesicular types probably represent planes along which the volcanic gases accumulated in the denser type. In the massive basalt the bands are lighter in color than the associated rock. The vesicles of the Blackjack basalt have not been filled up so as to form amygdules but they are often lined with a thin deposit of carbonate or a secondary green mineral (chlorite?).

On microscopic examination the Blackjack basalt is found to be similiar if not almost identical with the Owyhee (Columbia River basalt). Blackjack basalt contains feldspar phenocrysts with a maximum size of 1.3 x 0.55 mm. and an average size of 0.8 x 0.3 mm. A smaller generation of feldspar phenocrysts average about 0.2 mm. in length. Augite phenocrysts attain a maximum size of 0.5 mm. in diameter but a larger portion of the augite crystals are 0.5 x 0.2 mm. in length.

Pliocene Basalts.

The Pliocene Period was not one of great volcanic activity as were the preceding Miocene epochs, and it furnished only a few basaltic flows in the state.

The first mention of a Pliocene basalt is made by Hodge (42) in 1925, stating that the top of the Middle Sister is a black basaltic cone, composed of scoriaceous and loose angular boulders which appear to have come from a vent at a period not farther back than the Pliocene.

"Farther northward on the west edge of Collier Glacier stands Cirque rock which has an upper surface similiar to that of Black Hump. This flow of olivine basalt must have come from a source further east. When it poured out of some orifice to the east the basal portion of the Middle Sister must have been in existence in order to afford the surface upon which these rocks now rest and upon which their parental lava once flowed."

Kirk Bryan (7) in 1929 and Renick (64) in 1930 in articles on the Owyhee River list a group of basaltic flows, 400' thick covering about 50 square miles of an area bordering the lower Owyhee River, as the Grassy Mountain basalt. They give the age of this formation as Pliocene or late upper Miocene (?).

The Grassy Mountain basalt is composed of a group of flows individually not over 200 feet thick. They contain olivine as an essential constituent, and in this respect it is unique since it is the only rock in the area in which olivine was found. As observed in hand specimen, this basalt is generally massive but contains amygdules that are generally completely filled with carbonate. In color, most of the rock approaches black with a faint greenish tint. However, in places the usual dark color grades into a reddish or red-brown color with here and there purple tints; areas of this reddish type of rock are often an acre or more in extent. The reddish portions have also red-brown phenocrysts that are visible in hand specimen.

The texture is diabasic-ophitic, containing phenocrysts of olivine averaging 2x1.2 mm. in a ground mass of plag and augite with some hypersthene and minor amounts of magnetite. The phenocrysts of olivine are commonly well-developed but frequently partially or entirely altered to iddingsite although the outline of the original grain of olivine is still distinct. Not only is this basalt distinctive because of the presence of olivine, but the feldspars are basic bytownite with average composition ab_{25} an_{75}. Approximately 50% of the rock is composed of this basic feldspar, the crystals of which are 0.3 mm. long.

Pleistocene Basalts

Basalts of the Deschutes Plain.

(Madras Basalts of H.T. Hodge)

The basalts of the Deschutes plain were first separated from the underlying Columbia formation by Thomas Condon (18) in 1879 in a treatise "on some points connected with the igneous eruptions along the Cascade Mountains of Oregon", in which he states "thirty miles south of Klickitat, Des Chutes hill composed of basalt flexed and tilted, and broken, yet continuous: an evident outflow from the neighborhood of Mt. Hood.

As to the history of the deeply excavated interspaces we may take the one nearly east of Mt. Hood. The Des Chutes Hill, one of these off-shoots already described, is its northern barrier, and we make it our standard of record. That this excavation was once 2,000 feet deeper than it is now is proved by the two facts that, first, the Des Chutes River has cut its channel through its present filling of basalt without reaching the bottom, and secondly, that this great thickness of rock lies in undisturbed and unbroken level. 26 to 30 distinct flows may be counted in the section, at the crossing of the Des Chutes River. This later basalt is dark in color, dense in structure, and easily distinguished from the basalt of the neighboring hill, which has a brown color and is lighter. These later outflows filled up this vast excavation, then spread eastward and northward till they reached the outlying elevations of the foothills of the Blue Mountains. A well defined belt of sedimentary rock marks the strictly eastern limit of this outflow along the side of Antelope Valley and the John Day River. The nearest centers of eruptive outflow, other than those of the Cascade Range here, would be from the western spurs of the Blue Mountains. The largest of these was an eruption from the neighborhood of Camp Watson. It flowed into what seems to be an old meandering valley of the John Day River. It appears to have filled up the valley and set the waters to excavating one for themselves. This old valley full of basalt is now a mountain 1,200 to 1,500 feet above the place. The mold in which its mass cooled has long since been washed or quietly worn away. This Blue Mountain basalt can be easily distinguished from that of the Cascades. It is filled with granulations of a dark pyroxene, that gives its weathered surfaces a postulated appearance.

The undisturbed basalts that have filled up those vast excavations constitute a second series of operations in the region."

Condon differentiates between the Columbia River basalts and later flows through the observed facts that: (1) the later flows are undisturbed and, (2) fill canyons in the older topography. He does not, however, prescribe any definite age to either formation.

J. S. Diller (25) in 1884, mentions a low, broad arch lying, at elevation 3300' to 5600', not less than 75 miles in diameter. Neither does he give the exact age, placing them as Post-Miocene, nor does he differentiate between the undisturbed basalts and overlying andesites, leaving the impression that all are andesitic.

Jacques Redway (63), 1901, gives a more or less popular account on the great lava flood. He speaks of both the Deschutes canyon and Snake River canyon flows in the same sentence. Noting the fact that a large number of craters, the source of the Deschutes flows, and listing them as the offspring of larger fissure eruption.

Waldemar Lindgren (49), 1902, restricts the use of I. C. Russell's "Columbia Lavas", "to the basaltic lavas of the Miocene to distinguish between different kinds of lavas of Pliocene and Miocene". This seems to be the first definite step in the differentiation of the Columbia lavas as to age and Lindgren evidently recognises the presence of younger basalts in the state although he gives no specific case.

I. C. Russell (67), 1903, gives a good description of the basalt east of Prineville—"a 650' series, correlated with the extended lavas of the Des Chutes Plain, only one flow of which extends west to Prineville, the thickness of which determines the width of the valley." He does not mention the Columbia River Basalt which underlies this formation in this vicinity.

Russell also gives a good geologic description of this Deschutes Plains formation, in which he states that "the valley of the Deschutes, before it was filled so as to produce the broad generally level surface which is at present its most conspicuous feature, was from 20 to 30 miles wide in the portion west of the Paulina Mountains and Powell Butte, but perhaps had a less width farther north. This large valley, as may be judged from the character of the portions of its bordering slopes now exposed to view, was produced largely by erosion and was at least 800 feet deeper in its central part than the widely extended sheet of basalt forming the surface of the present plain. The material which partly fills the old valley, consists largely of water-laid volcanic dust and lapilli, of which sections 700' deep are exposed along the lower portion of the canyon of the Crooked River and in the adjacent portion of that of Deschutes River. The total depth of this deposit, however, is as yet unknown, as its bottom is not exposed. After the volcanic dust and lapilli, together with minor quantities of sand and clay, was deposited, a sheet of basaltic lava, in general 80' thick, was spread out. Possibly two or more sheets of lava were formed at about the same time which are so similiar that their recognition is difficult and they appear to represent but a single outpouring."

Hodge (45) calls the basalts of the Deschutes Plains, Madras basalts after the type locality of Madras, Oregon. The general character of the formation may be stated in his words.

"Madras Formation covers a large area it may extend as far south as Bend its eastern boundary extends from near Prineville, north to Hay Creek, and from these localities to the Deschutes River at Coleman.

To the north its eastern boundary for the most part lies only on the west side of the Deschutes river. It crosses to the north side of the Columbia River only near Lyle. It extends at least as far westward as the foot of Bald Peter and Mt. Wilson. It is composed of six flows of basaltic and andesitic lavas, separated by torrential and lacustrine deposits.

The upper flows are andesitic in character, and the lower ones basaltic.

The Madras formation lies unconformably upon the mature erosion surface of the Clarno, John Day and Columbia River Basalt Formations, as briefly described above. A few islands, such as Powell Butte, protrude through this sea of lava. Where the Madras formation lies on John Day beds its torrential beds are composed of materials derived from John Day."

Hodge (45) in 1930 describes this Madras formation as consisting of lava flows and torrential interbeds of ashes, sands and gravels.

"The Madras formation was the result of the damming of the Deschutes River during the glacial period. The streams were all overloaded and deposited their debris over the lowlands in the western half of the area" (north central Oregon). "Contemporaneous volcanism furnished lavas which sealed the torrential beds in layers and they are preserved as such to this day."

"This surface (that furnished by the lava capping) is perfectly flat and monotonous except for certain feeding volcanic buttes which rise above it, such as Round Butte, Bald Peter, North, Middle and South Butte, He He Butte and a small butte southeast of Teller Butte."

Madras Topography.

The Madras topography where determined by a lava capping flow, according to Hodge (45), "is perfectly flat, with here and there a thin soil covering, but it is usually barren and treeless except for sage and juniper. Traced from north to south or from east to west the surface rises, not by a slope, but in great steps, each determined by a lava flow. To the west the surface has been traced to in great embayments into the foothills of the Cascade Mountains.

Post-Madras Basalts.

Intercanyon Basalts.

An interesting feature of the Deschutes Plain region is the post-Madras basalt which occupies the channels of the Deschutes and Crooked Rivers in the general vicinity of Prineville, Terrebonne and Bend.

Russell (66), 1905, was the first person to publish extensive work on this formation. The following is an abstract of his treatise: "After the broad, ancient valley of the Deschutes had been filled to a depth in excess of 700' with loose stream-deposited debris, consisting mostly of black volcanic sand and gravel, and this material covered by the widely extended sheet of basalt now forming the surface of the major portion of the Deschutes Plain, the rivers displaced from their former courses flowed across the young lava plain and excavated canyons in it, which, in the case of Deschutes and Crooked Rivers, are a mile wide and over 800' deep. Next came a flow of molten basaltic rock, which entered the canyons and filled them to a depth of over 550' for many miles. Subsequently the same streams, again displaced but still confined to their former but deeply filled canyons, resumed their work of erosion and cut in solid basalt, the inner canyon described above. In the portion of the canyon examined the task of cutting through this layer is as yet incomplete and the rivers flow swiftly over solid, compact basalt."

"This is one of the most remarkable instances known of a river struggling, as it were, to maintain its right of way against the opposition offered by stupendous showers on downpourings of volcanic dust and lapilli and by vast outflows of lava which hardened into dense, resistant rock. The time occupied in the excavation of the outer canyons was probably not great, as the material in which these were excavated, with the exception of the covering sheet, was loose and incoherent, but the inner canyons, in places, and in distances in several instances of at least 2 or 3 miles, were cut in hard, compact basalt, and their erosion to a depth of 550 feet must have required many thousands of years."

Hodge (43) in 1930 is the other published reference of the intercanyon basalts which he terms "Intercanyon Benches". He states "after the canyons were cut in the Madras surface renewed vulcanism sent great lava flows down these canyons especially in the vicinity of the Crooked River. Some of these lavas have been removed but where they remain they form the picturesque and prominent benches on the sides of the older canyons."

Recent Basalts.

The recent basalts are widely distributed over the state, the most extensive flows occuring in the southeastern portions at Jordan and Bowdin Craters in Malheur county, at the Diamond craters and along the south fork of the Malheur river and Crane creek in Harney county. These craters gave rise to a very pahoehoe type of lava (Smith 75) and were first described by Russell (68) in 1905. Russell recognizes their geologic recent age and Smith (74) states that they cannot be over 500 years old. The Bowdin Crater flows occupy an area of 100 square miles and reach a maximum thickness of 600' according to Russell, who states that the radial overflow of lava was in thin sheets of basaltic flows, the more easily fusible of lavas. Diamond craters, according to Russell (68), and Bowman (5) 1911, give rise to a lava flow which dammed the channel of the Malheur River in the vicinity of Mule River and caused the formation of the basin of Harney and Malheur lakes. The surface of the lava is only about 10' to 15' above the normal level of Malheur Lake. The pounding of the water above the lava dam causes the entire region now draining into Harney and Malheur lakes, about 4500 square miles in area, to be removed from the Pacific slope drainage and added to the drainage of the Great Basin.

The flows from Jordan Craters arise from four distinct craters and dam Cow Creek to form the Cow Creek lakes.

The great majority of recent cones and lavas are located along the eastern boundary and central portion of the Cascade Range. Many of them are to be observed especially around Mt. Newberry.

Some of these cones were described by Russell (68) who states that "a large number of comparatively small, black or reddish, conical elevations, some of them with depressions in their summits, are clustered about the base and on the side of Mount Newberry, but more especially on the north and south of the central elevation. These secondary hills have the form and color of basaltic cinder and lapilli cones, and trending about northeast and southwest are bare of trees, though the adjacent land is densely forested reveals the presence of a rough lava flow probably of basalt." One was visited which, "situated about 4 miles west of Paulina Lake, was found to be a basaltic crater built of lapilli, with a well defined rim about 150' high on the outside, inclosing a depression approximately 100' deep and 600' across. This crater is in the region traversed by the glacier which flowed out of the Newberry Amphitheater and is unglaciated, is evidently of post-glacial age. It is overgrown by trees, however, and is probably older than the bare, black lava stream to the south of Mount Newberry and also older than Lava Butte."

"Lava Butte is a conspicuous lapilli cone with a deep crater in its summit 12 miles slightly west of Mount Newberry and about two miles east of the Deschutes River at Benham Falls." (It is about 12 miles east of the city of Bend and 1/2 mile off the present Dalles-California Highway). "The cone of the Butte rises about 500' above the adjacent forest-covered country, and is composed of basaltic lapilli and scoriaceous fragments varying in size up to 3 to 4 inches in diameter"........

"The lava from Lava Butte escaped from it through a tunnel at its base on the south side," (Russell 68) flowing north and east and blocked the Deschutes River forming the present Benham Falls.

He states its age as post-glacial, and attributes its existence to a fault, starting near its south base and extending a mile southward in the old basalt. The fault "perhaps indicates the course of the break which permitted the volcanic conduct, that built Lava Butte, to gain the surface and is of recent date." Evidently the 'post-glacial' age given the lava from the Butte is meant to be of Recent age.

"About 2½ miles south of Lava Butte in a nearly level forest-covered region, where the surface rocks are basaltic lavas of earlier date than the lava discharged from Lava Butte, there is an open trench about 400' long and 50' wide, with nearly vertical walls of from 30 to 40 feet high. The trench is due to the falling in of the roof of a lava tunnel and its bottom is composed of angular blocks of basalt variously inclined. The tunnel proper is 2 miles long and like several others in the same region, is due to the outflow of a lava stream after a roof from 30 to 40 feet thick had been formed by the cooling of the lava above it," Russel. I. A. Williams, (83) in 1923, also gives a very good description of this same tunnel. According to Russell (68), who has published the only extensive work on the Paulina mountains there are "a score or more" volcanic piles in the vicinity of Mount Newberry, "a part of a much larger group, which includes the 50 or more craters in the neighborhood of Button Springs and also probably part of a still larger number of similiar topographic forms situated to the south of Mount Newberry and known in part as the Walker Range." If this is true, the evidence of local basaltic flows of Recent age from adnate cones along the eastern boundary and the central portions of the Cascade Range is further strengthened since Hodge, (44) 1925, states that "it would appear that the last event of volcanic character in the Jefferson country dates but a short time back, and that this volcano activity follows the same line of weakness upon which Mt. Jefferson stands. Despite the fact that Mt. Jefferson in the main was built up of keratophyric rocks, vulcanism was able at the same place to reopen its conduit and pour out over all parts of its surface, ash, agglomerate and lava of basaltic character.

Diller (25) in 1884, makes the statement that "the great peaks of the (Cascade) range are all remnants of old craters. The larger ones form the most prominent peaks of the system, and, although post-Miocene in age are older than many of the smaller ones, mainly cinder cones, which retain their crater-like form more or less perfectly, as a rule, also, the latter are basaltic, while the chief mass of the larger ones is andesitic.

The Cascades represent a zone of weakness with flows originating in close proximity to the foci of the larger and older flows of andesite which make up the superstructure of the range. Along the summit of the Cascades at the Three Sisters, Hodge (42) has described a recent lava flow and Fairbanks (34) has also shown recent basic lavas there. Hodge (43) has described a recent 'black and white' basalt flow "which poured down the west side of Mt. Jefferson into Milk Creek valley to 1520'. The trail from Jefferson Park at a point where it turns south to Woodpecker Ridge shows the north side of this flow. This flow extends from this point down to the north side of Milk Creek valley and everywhere lies on top of glacial rock." "South of Mt. Jefferson is the double cratered Twin Cinder Peak and to the west of it is North Cinder Peak. South of them to Three Fingered Jack is a whole line of craters, cinder fields and flows. A large flow extends southeastward from North Cinder Peak, another similiar flow extends southeast down the valley of Jefferson Creek. On the north side of Mt. Jefferson are several recent craters."

H. T. Stearns (75) 1929, states "that the entire area around the upper McKenzie River is occupied by basaltic lava flows that issued from numerous vents on the summit of the Cascade Range from the late Tertiary to geologically recent time. Many of these flows are so new as to be nearly bare of vegetation."

"The lava which forms the valley floor above Lower Falls is of the Pahoehoe type, with relatively smooth surface, satin or shiny crust, and ropey structure. It is full of lava tubes and joints, and the lava dunes and other features of the original surface are well preserved. It is of geologically recent origin and may have flowed into the valley within the last 100 years. The flow came from the crest of the Cascade Range near Belknap Crater where it is chiefly of the 'Clinkery' type of basalt.

or aa lava, with the bristling of a stiff overcooled fluid on the point of solidifying. McDonald (54) lists a fine-grained dark basalt on the south edge of Bohemia mountain, intrusive in the andesite.

Southward at Crater Lake, Diller (23) 1902, has described a number of basalt cones which are later adnate cones on the lower slope of the great crater and were limited to the outer slope of Mt. Mazama. These cones were probably the source of the recent basalts which flowed southwestward down the channel of Rogue River and formed the "Natural Bridge" at Union Creek and the Cascades at Union Falls which have been described by Diller (24) in 1916. These basalts occurred before the dacitic eruptions of tuff but are post-glacial in age. "The basalt still shows the ropey forms in which it congealed and the bubble cavities or vesicles formed by the steam that nearly all lavas contain."

Farther south where the Klamath River makes its way through the gap in the Cascade Range, Diller (24) has noted the fact that the river is "blocked by a comparatively recent flow which formed a dam which, by pounding back the river, has contributed to the formation of the lakes and swamps of the country."

On the western side of the Cascades near Medford, recent basalts at Table Rock have been noted by Howard A. Powers (62) in 1926.

Petrography of the Recent Basalts.

Aside from the difference in localities in which they are found, the recent basalts, where petrographic descriptions have been given, are all alike in mineral composition. The rocks as a whole contain olivine and basic striated plagioclases. However, in some cases where olivine is absent the mineral hypersthene makes its appearance. Patton in his petrographic description of Crater Lake basalts states that "absence of olivine in the basalts in which hypersthene is unusually abundant is a further corroboration of the fact that the development of olivine in a basalt is not so much dependent on the chemical composition as upon the conditions of solidification" and refers to Rosenbusch 'olivine occurs most sparingly in the basalts of a hypidiomorphic or of a doleritic type'.

Patton classifies his basalts in 4 main types: Interstitial, fluidal-interstitial, porphyritic-interstitial and andesitic basalts. The composition as shown in his detailed descriptions with analyses remains comparable thruout all the types with the main differences being shown in texture fabric and grain. The total silica composition varies from 52.9 to 58.6% with an intermediate analysis which shows 56.9% of silica. The other constituent minerals show the same variance, the greatest difference being shown in Fe_2O_3.

In all localities a basalt with a glassy base plays a subordinate role to holocrystalline ones and the structure is dominated by the feldspars.

Other writers giving petrographic descriptions of recent basalts are: Hodge (42), who gives a description of Recent basalts of Mr. Jefferson, Stearns (75) of the Belknap Crater flows, Waters (80) gives a very thorough description of the Glass Butte basalts and Russell (68) gives a very meager description of the Recent basalts in south central Oregon.

Basalts of Undetermined Age.

Pardee and Hewitt (61), 1914, call certain lavas lying above the Mascall formation "Younger basic lavas" giving no definite age to them. These basalts are widely distributed over the northeast portion of the Sumpter Quadrangle and occupy the drainage basin of the Middle Fork of the John Day River and some adjacent lands. They also appear in considerable areas in the northwest quarter of the quadrangle and form patches elsewhere.

They are dark-colored, fine-grained rocks weathering to shades of gray. Porphyritic phases are abundant containing lath-shaped phenocrysts of Olivine. The basalts show platey and columnar jointing and weather to form small cliffs and bare knobs. They are composed of separate flows, local in origin and extent, but closely related in age. Their source is easily recognisable in the eroded volcanic necks of the quadrangle.

Diller (28) in 1884, has described an "eruptive rock which is quarried twenty miles east of Albany, on the western slope of the Cascade Range." The composition of this rock is that of a diabase with an admixture of rhombic pyroxene; but in its general facies and structure, as well as in the character of its alteration products it is closely related to the gabbros. Rocks of the same character high up in the mountains, are abundant a short distance, southwest of Mt. Hood. While it has long been known that the Cascade Range is built up chiefly of Recent lavas, it is becoming more and more evident that eruptions of gabbroic and granitic

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Tuck, (77) in 1927, located basalt flows and necks at Sawtooth Rock in Curry county which were largely made up of feldspar and pyroxene with some quartz. These rocks vary much in texture and the feldspar is much altered and full of inclusions.

Washburn (81), 1914, in "A Reconnaisance Report on the Oil Possibilities of northwestern Oregon" reports basalts in various counties of northwestern Oregon to which he ascribes no definite age.

He reports fine-grained and also diabasic basalts occurring in dikes, sills and intrusive in west Lane county at Heceta Head, Cape Perpetua and throughout the country. In Tillamook county, five miles east of the town of Tillamook flows of basalt breccia are found. These flows are composed of a hard, dark-blue amygdaloidal basalt with cavities filled with calcite and zeolites.

In Clatsop county, Washburne reports a dike 50' wide on Tongue Point trending northeast and southwest and another dike composed of basalt at 3/4 mile east of Olney which is 200 feet wide. Silver Point is made up of two basaltic dikes trending N., 65° E. In T. 7N., R. 8W., dikes may be counted by the hundreds. Along the coast line there are basalts at Cape Foulweather and south of Tillamook Head. In Polk county, the shale at Falls City and Monmouth is intruded by diabase and basalt.

J. S. Diller (22), 1896, describes Meare's Point as a sheet of columnar basalt which occurs near high-tide level, and enable the waves to cut caverns of considerable dimensions. These in time enlarge and join forming arches, which when broken, leave pillars and ledges to mark the line of an earlier cliff.

In an analysis of a basalt from Mt. Thielson near Diamond Lake, F. W. Clarke (15) in 1884, gives the total content of $Si\ O_2$ as being 55.68% with other major constituent minerals as Al_2O_3 (18.93%) Fe_2O_3 (8.73%), $Fe\ O$ (7.99%) and $Ca\ O$ (4.86%). Showing that the rock of Mt. Thielson is a true basalt. No definite age was given this basalt.

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PETROGRAPHY

of

OREGON BASALTS

PART

II

Purpose.

The purpose of this petrographic study is to provide a systematic classification for the basalts, and to obtain data concerning the characteristics of each formation so that in the future this preliminary work may be extended into definite and extensive classifications of a more exacting nature.

Method.

The problem was attacked megascopically and after careful binocular study the basalts were grouped into types which were based on crystallinity, granularity, fabric and specific gravity with subdivisions of less prominent characters such as weathering and a high percentage of ferric iron.

From this preliminary megascopic grouping, typical specimens were selected and thin sectioned. A total of 71 thin sections were studied and the rocks which they represented were grouped into mineralogical types following the system established by Dr. E. T. Hodge in his "Quantitative Mineralogical and Chemical Classification of Igneous Rocks," (U. of O published 1927).

The basalts were found to fall naturally into the following types arranged in their order of their importance:

1. C 1-3 VII	5. C 1-3 V
2. B 1-3 VII	6. B-C 4-6 II
3. B-C 1-3 II	7. B 4-6 VII
4. B 1-3 V	8. C 4-6 VII

The basalts were found to fall, predominately, into B and C classes with only a very few A and D rocks, in order to condense as much as possible and because of the large number of types which would naturally follow the uses of all four classes, the basalts were placed in two great classes B and C. The B class including all basalts under 50% afeloid components and C class all basalts above 50% afeloid components.

Sub-types and divisions of sub-types have been based on granularity, weathering and other characteristic features which, in the opinion of the writer, warrants a separate division, explanation of these sub-types follow under the type descriptions.

Type

C 1-5 VII

The most important type from the standpoint of number. It is made up of 156 specimens of Columbia River basalts, 4 specimens of Cascade basalt and 14 of Coast Range basalt specimens.

The type is undoubtedly the most representative division of the Columbia River basalt formation.

Megascopically, the basalts are microcrystalline being made up of very fine-grained feldspars of lath-shape imbedded in a very dark, dense and somewhat glassy ground mass. They have a maximum specific gravity of 3.04; a minimum of 2.63 and an average of 2.86. Their porosity is negligible, averaging not more than 2%. They show very irregular fracturing.

The 16 thin sections studied show that this type of basalt consists of a very large group of fine-grained, equigranular, hypocrystalline basalts with varying percentages of glass. The glass formed at the same time that the second generation of feldspars and augite or earlier, in the latter case it took the place of the second generation, forming a dense glassy groundmass acting as a matrix for a single generation of augite and feldspars.

The type includes, also, a group of holocrystalline, seriate porphyroid, medium-grained rocks. A very small group of Coast and Cascade Range olivine basalts with a very high percentage of magnetite.

Essential Minerals.

Olivine: Callaghan, 1927 (U. of O thesis) shows that the olivine in Coast Range basalts varies from .05 mm. to 4 mm. with an average size of 2 mm. anhedral to euhedral olivine crystals of two generations. The first "are anhedral as all the borders are curved. The edges of some of the crystals have a 'fjorded' effect, the indentations now being filled with augite and some magnetite. These effects have been produced by resorption. The second group differ greatly from the first in that they are larger, euhedral and light green in color. Unlike the others they include numerous inclusions of magnetite, plagioclase, augite and the clear olivine. (Showing that they surrounded particles of magma). They also show the characteristic olivine fracturing." The olivine in these slides show parallel extinction, negative elongation, positive character, and very strong birefringence.

Megascopically, the large olivine phenocrysts appear as light green to dark brown sub-rounded crystals imbedded in a groundmass of microaphanitic minerals. The dark brown variety of olivine generally shows a characteristic sub-metallic luster.

The presence of olivine in this type is the basis for a sub-division of the main type.

Augite: All slides excepting one with 60% glass shows the presence of augite which crystallizes in two distinct generations; the first generation has a maximum size of .5 mm. and a minimum size of .2 mm and averages

.3 mm. anhedral masses ophitic to first generation plagioclase crystals or subhedral lath-shaped crystals which show more perfect growth. The second generation is granulitic from .1 mm. to very fine .01 mm., averaging .05 mm., granules which are ophitic to a second generation of plagioclases.

The augite is of later crystallization than magnetite since it contains inclusions of that mineral and occurs ophitic to plagioclases showing that it is intermediate between plagioclase and magnetite in order of crystallization.

The augite shows approximately 45° extinction, is light green in color is non-pleochroic, shows second order birefringence and positive character.

Six slides show an alteration of this mineral to chlorite which rims the crystals and stains the neighboring minerals a light yellow-green color. The maximum alteration shown was 5%, minimum trace and average 2%.

Diopside: Diopside or colorless augite has been found in three thin sections. A maximum of 25% minimum of 4% and an average of 10%.

The occurrence of diopside is essentially like that of augite, crystals of each occurring side by side. The mineral varies from augite in its optical properties since it is colorless, non-pleochroic, shows slightly lower birefringence, 38° to 40° extinction and is of positive character.

A trace of alteration to chlorite was found in one slide.

Plagioclases: The plagioclases occur, with exceptions in two generations, the first being more basic than the second. The first generation show slight resorption and fracturing and are of larger size than the second generation which also shows little fracturing, no resorption and give a characteristic fresh appearance.

In slides of a single generation of plagioclase the groundmass is invariably composed entirely of glass and the feldspars are small microlites with a fluidal fabric. The microlites being less than 0.3 mm. in size.

First generation plagioclases vary in size from a maximum of 1 mm. to a minimum of 0.2 mm. with an average size of 0.4 mm. They occur as tabular crystals and lath-shaped crystals. The determination of the plagioclases was based mainly upon extinction angles and upon index of refraction. Anorthite was found to be the first generation plagioclase in 4 specimens. It showed extinctions angles of (-64 à -26) on microlites; 42½° on tabular crystals; 54° on cross sections and an equal extinction of 50° on albite twins. Anorthite gives an approximate index of 1.58.

Basic labradorite was determined as the first generation plagioclase in five specimens it showed -40° extinction on microlite and from 36°-38° maximum equal extinction on albite twins.

Only two specimens show medium labradorite as first generation plagioclases. They give maximum extinction angles of -32° on microlites and ± 32° on albite twins.

When occurring as the most basic spar, acid labradorite is found as a single generation in all specimens except one. It shows a maximum extinction of 22° on microlite sections and a maximum of ±30° on albite twins.

Second generation plagioclases vary in size from a maximum of 0.2 mm. to a minimum of 0.08 mm. the average size is 0.1 mm. They occur as lath-shaped microlites on very fine cross-sections. The second generation occurs as basic labradorite in one specimen, as medium labradorite in three specimens and as acid labradorite in one. One thin section showed 20% of andesine of 0.15 mm. laths which gave maximum extinction angles of -70 on microlites.

Plagioclases of the first generation are the only minerals visible in hand specimen. They occur as 0.5 mm. striated lath-shaped crystals.

Accessory Minerals.

Magnetite: Occurs in all slides the greatest percentage being 20% and the smallest 10% with an average percentage of 12%. In size magnetite varies from 0.4 mm. subhedral crystals to 0.01 fine dust-like grains; but the average occurrence is in 0.1 mm. equant square grains.

Magnetite is thoroughly disseminated throughout the groundmass and occurs as inclusions in all crystals and is therefore older than other minerals.

In two slides it shows 3% and 8% alteration to hematite. The hematite occurring along weathered portions of the specimens as fine red spots.

Only in few specimens may the magnetite be distinguished in hand specimens since the rock is dark enough to make invisible any magnetite that could be seen in lighter rocks.

Secondary minerals:

Chlorite: Occurs as a dark green stain which surrounds augite, its parental mineral. In rocks containing high percentages of augite, the chlorite seems to follow definite fracture cracks and may be recognized in hand specimens as light green sub-parallel lines in an otherwise dark specimen. Its typical occurrence in more or less vesicular rocks is the lining of the vesicles where it occurs as a light yellow-green stain.

It is anistropic in some cases but in most instances it occurs as dull green earthy masses with no optical properties.

Hematite: A purely secondary mineral the alteration product of magnetite along the weathered edges of the rock. It makes its appearance as fine red dots. In thin section it shows the following optical properties; red color, slight pleochroism, positive elongation and negative character.

Glass:

Occurs in varying quantities as the matrix for first or second generations of crystals, a maximum of 80% was noted in one slide while the average specimen shows 10%. When in sufficient quantity this glass is the sole constituent of the groundmass. It gives the lustrous black color to the rock and appears dark in thin sections. Fine dust-like fragments of magnetite included in it probably gave it its dark color.

A far different type of glass occurs in a large group of Columbia River basalts, its occurrence is interstitial to an otherwise holocrystalline rock. It has a distinct reddish color in thin section and shows perlitic fracturing. The glass has been determined as Palagonite and occurs, interstitialy to the second generation of plagioclases and augite. It constitutes a relatively high percentage varying from 10% to 15%. It differs from the brown-black glass in that it occurs haphazardly throughout the groundmass and does not act as the matrix for the earlier generations.

Due to the fact that the present of palagonite lends a very characteristic rust-red color to Columbia basalts (a characteristic heretofore considered as a weathering phenomena) a sub-division is thought advisable for this group.

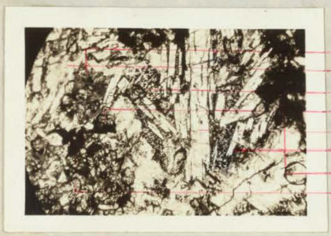
Genesis

This group of basalts is characterized by its fine-grained, hypocrystalline, equigranular texture, showing that the magma from which it was formed cooled fairly rapidly, consequently it did not allow sufficient time for the complete crystallization of the essential mineral. The presence of glass in varying quantities indicates this fact. The diabasic-ophitic-granulitic fabric and the lack of a fluidal fabric denotes a magma comparatively still at the time of freezing.

The order of crystallisation is: __first__, magnetite; __second__, when present, olivine; __third__, augite followed by (3a) first generation plagioclase; __fourth__, granulitic augite followed by second generation plagioclase (4a); __fifth__, palagonite. The fourth and (4a) series may each or both be displaced by a matrix of brown-black glass.

Type C 1-S VII

C-472p, a typical fine-grained, hypocrystalline, and equigranular Columbia River basalt.



diameters

Essential minerals:

Augite: 25%

.3 mm. subhedral crystals
.01 to 0.1 mm granules

Acid Labradorite:25%

.25 mm. laths-shaped crystals, fresh appearing and very slightly fractured, comprising the first generation plagioclase.

Andesine: 20%

.16 mm. lath-shaped crystals of the second generation plagioclase.

Accessory minerals:

Magnetite: 20%

.25 mm. irregular and subhedral crystals.

Secondary minerals:

Chlorite: Trace

Hematite: 5%

Glass: 5%

Genesis: See type description.

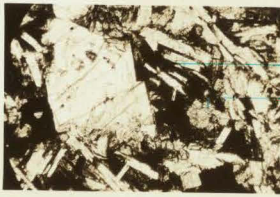
Occurrence: Elevation 1450' Tygh Ridge.

This type includes 64 specimens collected from many different type Columbia River basalt localities. From Arlington west to Middle Mountain and the included large area as far south as Prineville. Several specimens are included in the list which have been collected on the north side of the Columbia between Roosevelt and Lyle, and a few specimens from along the west side of the Cascade Range as far south as the Santiam River.

Type C 1-S VII

Sub-type 1.

C-642, a fine-grained, hypocrystalline, equigranular Columbia River basalt characterized by palagonite.



80 diameters

Essential minerals:

Augite: 23%

0.5 aggregates of granules

Diopside: 4%

.2 mm. subhedral crystals

Anorthite: 3%

0.6 mm. tabular crystals, fractured and resorped

Acid labradorite: 40%

0.2 mm. very fresh appearing lath-shaped crystals.

Secondary minerals:

Chlorite: 5%
Stain and earthy masses

Palagonite: 15%

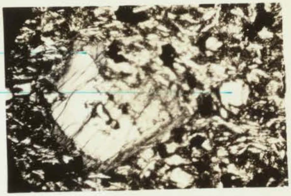
Occurrence: Middle Mountain basalt flow

Localities: 72 Columbia River basalts with the same general distribution as the type.

Type C 1-3 VII

Sub-type 2.

CR158, A holocrystalline, inequigranular, seriate-porphyroid basalt with olivine.



80 diameters

Essential minerals:

Olivine: 26%

10% 4 mm. anhedral crystals of the first generation
16% 2.5 euhedral crystals of the second generation

Augite: 27%

1% 0.5 mm. subhedral crystals of the first generation
26% 0.1 mm. granules of the second generation

Basic labradorite: 28%

0.4 mm. 0.1 mm. fine lath-shaped crystals

Accessory minerals:

Magnetite: 19%

0.4 mm. subhedral crystals

Secondary minerals:

Chlorite: Trace

Genesis: See under "olivine" of the type description
Occurrence: Flow basalt at Gwynn Knoll
Localities: 14 specimen from different sections of Callaghan's Hecota Head district, and 2 specimen from the Cascade Mountains in the vicinity of the Three Sisters.

Type

B 1-3 VII

This type is divided into three sub-types. Sub-type 1 includes 62 Columbia River basalts, 2 basalts of unknown relationship from due south of Long Butte (presumably Columbia River basalts) and 6 Clarno basalts. These basalts are fine-grained, dark gray-black and can be distinguished from the glassy black color of the type. C 1-3 VII Columbia basalts on this basis. The only crystals apparent to the naked eye are 0.2 mm. thin, lath-like, light colored striated plagioclases imbedded in a very fine-grained, dense black groundmass. Specific gravity tests show this group to be similiar to type C 1-3 VII in that the maximum, minimum and average specific gravities respectively of the B 1-3 VII basalts are 3.01, 2.64 and 2.84.

Sub-type 1 is divided into 3 divisions, (a) which includes those basalts with interstitial glass of the variety palagonite; (b) which show a high percentage of chlorite giving them a yellowish-green color; (c) a small group of deep red basalts which owe their color to the thorough impregnation of the rock with hematite stain, the result of the hydration of the magnetite while the magma was still in a molten stage. These rocks occur as thin crusts to flows or as very thin complete flows and give evidence of either heavy rainfall on the surface of the molten lava or a deposition of the flow under subaqueous conditions. The crystallized magnetite in the fluid being hydrated by the presence of water.

Sub-type 2 porphyritic phase of sub-type 1 which includes 12 Coast Range basalts, 4 Columbia River basalts and 1 clarno basalt. The phenocrysts of this sub-type constitute 25% of basic labradorite in the Coast Range basalts while in the Columbia River basalts their maximum is 15% and average is 5%. The porphyritic phase of the Columbia more resembles the C 1-3 VII basalts in color and general appearance except for large phenocrysts of light brown colored striated basic labradorite crystals giving enough feloids to the rocks for its classification in the "B" division.

The clarno basalt is fine-grained, light colored, with a high specific gravity and 20% of light colored striated basic labradorite.

Sub-type 3,a group composed of 7 Madras, 2 Clarno, 4 Cascade basalts and 1 Coast Range basalt, all of which show the presence of olivine. The basalts are seriate porphyroid, fine to medium-grained holocrystalline rocks. The only minerals apparent in hand specimen are olivine, as dark green to dull reddish-brown 2 mm. (maximum size) sub-rounded grains, and lath-shaped plagioclase crystals reaching a maximum length of 4 mm.

The Madras basalts show in 2 cases the presence of opal filling cavities, 1 case the opal is clear and in another case it is stained with limonite and takes the form of earthy masses.

The Cascade rocks are very fresh appearing basalts from recent flows and one specimen of dike basalt from the top of Sawtooth (H 530).

Sub-type 3: division a, Clarno basalts which in addition to olivine contain a small percentage of hypersthene (10%). These specimens are porphyritic basalts of dark brown color with a specific gravity of 2.7. They contain 10% of light brown glass.

Essential minerals.

Olivine: The maximum percentage of olivine occurring in the basalts studied was 16% the minimum 3% and the average 6%. They ranged in size from 0.2 mm. to 2 mm. with an average size of 1 mm. Their optical properties and evidence of age was identical to the type C 1-3 VII olivine basalts.

Hypersthene: Characteristic of clarno basalts occurring as badly fractured and altered, subhedral crystals showing a very regular carded fracture, parallel extinction, negative character, positive elongation, 0.012 birefringence, weak pleochroism and a light green color. The crystals make-up 10% of the slide and alter to 8% chlorite stain, their maximum size is 1 mm. and minimum size 0.8 mm.

Hypersthene is slightly resorbed, contains magnetite and augite inclusions and is highly fracture. These characters indicate development contemperaneous to or slightly younger than olivine.

Augite: Maximum percentage of augite is 34% minimum percentage 2% and average 20%. In some cases the augite occurs in 2 generations. The first ophitic to first generation plagioclases and the second generation ophitic to second generation plagioclases in which cases, the first generation augite does not exceed 10% and occurs as subhedral crystals with a maximum, minimum, and average size of 0.5 mm., 0.2 mm, and 3 mm. respectively. The balance of the total augite percent. being taken up by granulitic augite with average size of 0.08 mm.

Other properties, optical properties and evidence of age identical to type C 1-3 VII.

Alteration to chlorite is found in a trace in all slides to a maximum of 16%; the average being 8%.

Plagioclase: Similiar occurrence to type C 1-3 VII with noticeable exceptions of; first, an absence of andesine and, second, the occurrence in sub-type 2 of phenocrysts of basic labradorite crystals of tabular shape which reach a maximum length of 8 mm. and have an average length of 4 mm. The crystals average 10% of the rock and reach a maximum of 20%. The crystals show zonal growth, a high degree of fracturing and some instances the fractures are filled with glass and crystallised plagioclases and augite of the second generation. The absence of andesine indicates a slightly more basic character of the magma, although even in the "C" type it occurs only in small quantities as second generation plagioclase.

See type C 1-3 VII for optical properties.

Accessory minerals:

Magnetite: Identical to C 1-3 VII in occurrence, evidence of age and other properties.

Maximum, minimum and average percentages of magnetite found in this type are 15%, 10% and 12% respectively. They range in size from 0.05 mm. equant grains to 0.3 mm. aggregations of grains.

Secondary minerals.

Hematite: In only two thin sections was hematite noticeable as an alteration product of magnetite in (0269) it occurred along the weathered edges of the rock, and was purely secondary, while in (O-337) the alteration was of hydrothermal action and took place in the still fluid groundmass altering a large percentage of the magnetite to hydrous iron (hematite) which thoroughly stained the groundmass and phenocrysts giving a red color to the specimen as a whole.

Chlorite: Occurs as a secondary alteration product of augite replacing augite crystals in degrees varying from a faint stain which rims the crystals to a stage where the augite is completely altered. Chlorite is found from traces in all basalts of this type to a maximum of 18% with an average of 5%. Specimens with a large percentage of chlorite have a characteristic yellow-green color.

Hematite: See discussion under alteration of magnetite of this type.

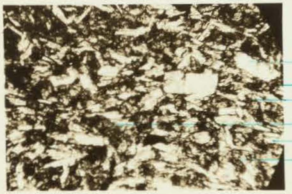
Genesis of type: Identical to type C 1-3 VII.

Type B 1-3 VII

Sub-type 1.

O-376, Holocrystalline, seriate homoid, equigranular

Columbia River basalt.



80 diameters

Essential minerals:

Augite: 25%
20% 0.05 mm. granules
5% 0.5 mm. subhedral crystals

Anorthite: 8%
0.4 mm. tabular crystals which show subparallel alignment and strain shadows

Basic labradorite: 46%
0.1 mm. to 0.05 mm. lath-shaped and small tabular crystals

Accessory minerals:

Magnetite: 10%
small equant grains and aggregates of grains to 0.3 mm.

Secondary minerals:

Chlorite: 10%

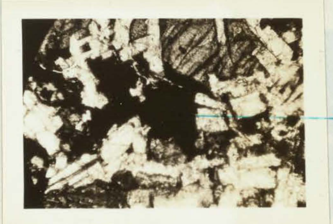
Occurrence: 2100' south of Clarno.

Localities: Columbia River basalt from many localities in north central Oregon and 2 Clarno basalts one (DC445) from 4 miles up Trout Creek from Ashwood and (O-363d) from near Sampson Mountain at an elevation of 3200'

Type B 1-3 VII

Sub-type 1 - Division a.

O-610. An equigranular, seriate homoid, fine-grained basalt with palagonite: typical of the Columbia River basalts.



80 diameters

Essential minerals:

Augite: 27%
20% 0.1 mm. granules
7% 0.2 mm. to 0.8 mm. subhedral crystals

Anorthite: 18%
1 mm. tabular crystals

Basic labradorite: 35%
0.5x0.1 to 0.3x0.1 lath-shaped and tabular crystals

Accessory minerals:

Magnetite: 10%
in 0.05 mm. equant grains

Secondary Minerals:

Chlorite: 3%

Palagonite: 10%

Occurrence: Flow, 1870' east wall of Hood River Valley

Localities: 10 Columbia River basalts from the Santiam River, Hood River and along the Columbia River between Hood River and Arlington.

Type B 1-3 VII

Sub-type 1 - Division b.

O-249, Equigranular or seriate homoid, fine-grained holocrystalline basalt with chlorite in quantities large enough to noticeably discolor specimens.

80 diameters

Essential minerals:
  Augite: 30%
    5% subhedral badly altered 0.3 mm. crystals
    25% 0.1 mm. to 0.05 granules
  Anorthite: 20%
    0.3 to 0.7 mm. lath-like crystals
    1.5 mm tabular crystals showing resorption and fracturing with glass inclusions
  Medium labradorite: 30%
    0.2 very fresh appearing lath-shaped and tabular crystals

Accessory minerals:
  Magnetite: 15%
    0.1 mm. equant grains to dust-like particles

Secondary minerals:
  Chlorite: 5%
    Following 0.1 mm. planes at right angles to the thin section

Occurrence: Due south of Long Butte; of unknown relationship but probably Columbia River basalt.

Localities: 3 Clarno basalts from Coyote Creek and Dry Creek, and 15 Columbia River basalts from a variety of localities from eastern and western sides of the Cascades in north central Oregon.

Type B 1-3 VII

Sub-type 1 - Division c.

O-887, Equigranular or seriate homoid, fine-grained, holocrystalline with ferric iron stain.

80 diameters

Essential minerals:

Augite: 10%
0.5 mm. subhedral crystals to 0.1 mm. granules
Diopside: 10%
0.5 mm. subhedral crystals to small granules
Anorthite: 20%
highly fractured and resorpted crystals varying from 2 mm. to 0.5 mm. in length
Basic labradorite: 40%
0.3 mm. tabular and lath-shaped crystals

Accessory minerals:

Magnetite: 10%
0.1 mm. equant grains

Secondary minerals:

Hematite: 20%
altering from magnetite by hydrothermal action in the magma. Occurs as stain and as definite crystalline masses of earthy form.

Occurrence: Flow basalt from 3125' near the 30 mile School

Localities: Clarno basalt specimen from 30 mile School and 7 Columbia basalts from widely separated Columbia River basalt localities in north central Oregon.

Type B 1-3 VII

Sub-type 2.

CR 191, A porphyritic basalt, holocrystalline, inequigranular, with fine-grained groundmass.

80 diameters

Essential minerals:

Augite: 20%
1% equant crystals to 0.3 mm. in diameter and
19% extremely fine granules
Basic labradorite: 30%
highly fractured phenocrysts up to 6 mm. long but with an average length of 4 mm.
Acid labradorite: 32%
lath-shaped crystals from 0.5 mm. to 0.05 mm. in length.

Accessory minerals:

Magnetite: 15%
abundantly scattered grains under 0.1 mm. in size

Glass: 3% in small, irregular, scattered areas.

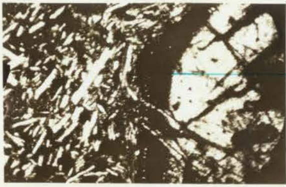
Occurrence: Basalt porphyry Sec. 28, T.16S., R.11 W., one mile southeast of Big Creek school.

Localities: 10 Coast Range basalts from Callaghan's area, and 5 Columbia River basalt specimens from along the Columbia River. A specimen of Clarno basalt from Alkalie Butte

Type B 1-3 VII

Sub-type 3.

O-269, A holocrystalline, seriate porphyroid, fine to medium-grained, Madras basalt with olivine.



magnetite surrounding a badly fractured and resorpted olivine crystal

80 diameters

Essential minerals:
- Olivine: 15%
  - occurs as large, badly fractured and resorpted anhedral crystals with a maximum size of 2 mm. and a minimum size of 1 mm.
- Augite: 15%
  - small 0.1 mm. granules
- Basic labradorite: 55%
  - large crystals 2 mm. to 0.3 mm. long all oriented with a definite position (sub-parallel) the smaller crystals parallel to different faces of larger crystals.

Accessory minerals:
- Magnetite: 15%
  - occurs as aggregations of 0.1 mm. grains around olivine crystals and as disseminations throughout the groundmass.

Secondary minerals:
- Chlorite: 2%

Occurrence: Madras flow basalt from 3350' above McAllister

Localities: Madras basalts from Schoules R. S., Stearn's Butte, Mill Creek and Smock Prairie. Recent basalts from Cinder Peak and Lava Falls, Dike Rocks, one from Sawtooth Mountain and one from the Coast Range in Callaghan's area.

Type B 1-3 VII

Sub-type 3 - Division a.

O-382, Seriate porphyroid, fine-medium grained, hypocrystalline Clarno basalt with hypersthene in addition to olivine.

hypersthene
basic labradorite
(note zonal growth)
acid labradorite
glass

35 diameters

Essential minerals:

Olivine: 7%
large 2 mm. subhedral crystals badly fractured and altered
Hypersthene: 10%
large 2 mm. to 1 mm. crystals with a corded fracture
Augite: 2%
1 mm. badly altered and fractured anhedral crystal
Basic labradorite: 30%
large 4 mm. to 2 mm. tabular and lath-shaped crystals badly fractured. In some crystals the fractures are filled with glass
Medium labradorite: 20%
fine lath-shaped and tabular crystals averaging 0.1 mm. in length, fresh appearing.

Accessory minerals:

Magnetite: 10%
occurs as 0.1 mm. equant grains and as aggregates of these grains in lath-like forms

Glass: 10%
large irregular areas of dark brown glass

Occurrence: Flow from 3200' at Kinzua

Localities: 3500' at Kinzua

Type

B-C 1-3 II

This group includes those olivine free basalts that have less than 10% magnetite.

The type is divided into two main sub-types:

Sub-type 1, holocrystalline, equigranular, fine-grained basalts; division (a), with high percent. of chlorite; division (b), inequigranular, porphyritic holocrystalline basalts.

Sub-type 2, hypocrystalline, equigranular, fine-grained basalts; division (a), hypocrystalline basalts in which glass is stained red by the presence of hematite (similiar to type B 1-3 VII, sub-type 1, (c)). Division (b) basalts of the Columbia River formation characterised by the presence of interstitial glass of the variety palagonite.

Microscopically this group of basalts fall close to the 50% feloid-afeloid dividing line, very fine, careful work would show a division of this type into B and C divisions but megascopically there can be no such division.

Essential minerals.

Augite: Occurs in two generations. In many instances the first generation is composed of subhedral crystals with an average size of 0.3 mm. and a maximum size of 0.5 mm. and does not exceed 10% of the total mineral constituents. The second generation is composed of 0.1 mm. to .01 mm. granules and make up the remainder of the total augite percentage which in the slides studied varied from 10% to 50% with an average percentage of 27%.

The occurrence, evidence of age, and optical properties of augite in this group is identical to that of type C 1-3 VII.

The common alteration product of augite is chlorite which varies from a trace in all slides to 20% in C-472b, the average percentage shown is 8%.

Diopside in this type was noted in only two slides both of which contained 10%. The size varied from 0.01 mm. to 0.1 mm. with an average size of 0.05 mm. all of granulitic form.

See type C 1-3 VII for further discussion of Diopside.

Plagioclase: Are identical to previous types studied with the exceptions of phenocrysts of anorthite in the porphyritic subdivision of sub-type 1, and the type is noticeable microscopically due to the presence of a third generation of Acid Labradorite in 0.01 mm. to 0.2 mm. lath-shaped crystals.

Due to the fact that the phenocrysts are anorthite and that the slides in some instances contain a third generation of acid labradorite which is the most acid plagioclase in the basalts of this type these rocks may be assumed as being more basic than previous types.

The phenocrysts of anorthite correspond to the phenocrysts of basic labradorite in the C 1-3 VII basalts. The anorthite is badly fractured and shows strain shadows, the fractures are commonly filled with second generation crystals and glass. All of the plagioclases are fine-grained being under 1 mm. in size with the exception of the porphyritic variety in which specimens the crystals reach a maximum size of 11.2 mm. x 4.6 mm. tabular crystals which make up an average of 10% of the total percentage of constituents.

Accessory minerals.

Magnetite: The percentage of magnetite in this type varies from 1% to 8% with an average percentage of 3%. In size, they vary from .01 mm. to 0.1 mm. equant square grains.

(DaF2) shows a slight alteration of magnetite to hematite.

(C-22) shows the hydrothermal alteration of magnetite to a red hematite stain which colors the entire rock a red color.

Secondary minerals.

Chlorite: Occurs as the alteration product of augite and is purely secondary to the solidification of the magma. For percentages see under alteration of augite. For further description see under type C 1-3 VII.

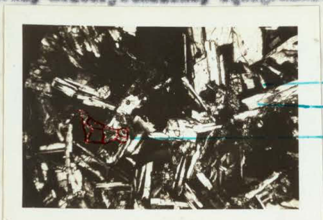
Hematite: Occurrence identical to type B 1-3 VII, sub-type 1, division C.

Glass. Two varieties: first, a brown-black glass which forms the matrix for first or second generation minerals depending upon the percentage of glass present, and, second, palagonite which occurs interstitially to the second generation plagioclases and augite. In the first variety the glass varies from 10 to 40% and in the second variety (palagonite) it varies from 8% to 12%.

Type B-C 1-3 II

Sub-type 1.

C-472d, Holocrystalline, equigranular, fine-grained.



80 diameters

Essential minerals:

Augite: 40%
varying in size from 0.1 mm. to 0.08 mm. granules
Anorthite: 27%
0.8 mm. to 0.3 mm. tabular crystals
Medium labradorite: 30%
0.8 mm. to 0.1 mm. lath-shaped crystals.

Accessory minerals:

Magnetite: 1%
0.1 mm. equant grains.

Secondary minerals:

Chlorite: trace

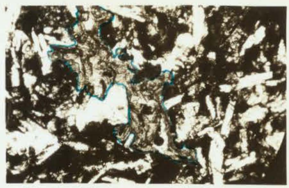
Localities: 37 specimens of Columbia River basalt taken from within an area as far south on the west side of the Cascades as the Santiam River at Detroit and as far east of the Cascades as Hermiston: 2 specimens of Clarno formation basalts; one from Current Creek and the other from T.8 S., R.13 E., at an elevation of 4320'. Three specimens from near Waldo and Todd Lakes are included in this sub-type and are probably recent basalts. Seven specimens of Coast Range basalts from Callaghan's area are also type rocks.

Type B-C 1-3 II

Sub-type 1 - Division a.

O-472b, Holocrystalline, equigranular, fine-grained with a high percentage of chlorite.

chlorite



80 diameters

Essential minerals:

Augite: 30%
5% subhedral crystals 0.3 mm. in length
25% 0.1 mm. to 0.05 mm. granules.
Anorthite: 20%
1.5 to 0.75 mm. lath-like crystals
Basic labradorite: 20%
0.6 mm. maximum length of lath-shaped crystals, average 0.4 mm. minimum 0.1 mm.

Accessory minerals:

Magnetite: 5%
0.05 mm. equant grains to dust-like particles.

Secondary minerals:

Chlorite: 20%
a green stain which completely replaces much of the augite granules and stains the surrounding minerals, occurring in definite bands

Glass:

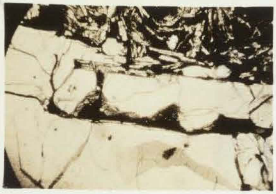
Palagonite: 5%

Occurrence: 2100', second highest flow from Tygh Ridge grade into Tygh Valley.
29 specimens of Columbia River basalt from east and west side of the Cascade Range in north central Oregon. 2 specimens of clarno basalt one from the south side of the Wasjeff hills and the other from Coyote Lake. 1 dike rock from Soda Creek on the west side of the Cascades and a recent basalt from southwest of Todd Lake.

Type B-C 1-3 II

Sub-type 1 - Division b.

D 104. Holocrystalline, seriate porphyroid, fine-grained groundmass.



anorthite
with fractures filled with
augite, basic labradorite
and glass

35 diameters

Essential minerals:

Augite: 10%
granulitic crystals varying from 0.1 mm. to 0.05 mm.
Anorthite: a single large crystal, 11.2 mm.x 4.6 mm., which
shows fracturing, with the fractures filled with glass and
second generation crystallizations. Parts of the crystal
show resorption and zonal growth and strain shadows are
very common in definite bands.
Basic labradorite: 10%
1 mm. to 0.5 mm. in lath-shaped crystals which show albitic
twinning in nearly all cases.
Acid labradorite: 15%
third generation crystals of lath-shape form varying in size
from 0.1 mm. to 0.01 mm.

Accessory minerals:

Magnetite: 1%
0.01 mm. dust-like grains

Glass: 1%

Occurrence: In Blalock Canyon, 1/2 mile from the Columbia River at
an elevation of 560'

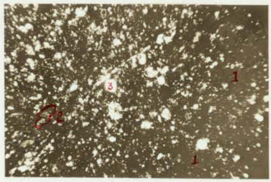
Locality list:
3 specimens of Columbia basalt from near Mayer park and a Coast
Range basalt 100 yards north of Creek North of Cummins Creek.

Type B-C 1-3 II

Sub-type 2.

BaF2, Hypocrystalline, equigranular, fine-grained glassy basalts.

glass (dark base) (1)
augite (2)
basic labradorite (3)



80 diameters

Essential minerals:

Augite: 10%
0.1 mm. to 0.01 mm. granules

Basic labradorite: 40%
0.1 mm. to 0.01 mm. cross sections of crystals
single generation

Accessory minerals:

Magnetite: 1%
0.01 mm. very fine dust-like grains

Glass: 49%
reddish-black variety which acts as a matrix for the crystals of augite, magnetite, and labradorite.

Occurrence: Near Baker, Oregon. (Formation unknown)

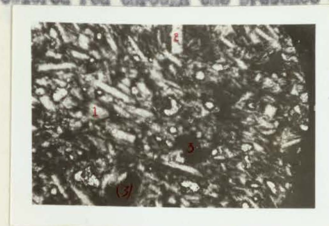
Locality list:
0-21 Was Jeff Hills
0-292 Mouth of Wolf Creek
0-374 4840', T.10 S., R.17 E., Sec., 1.

Coast Range Basalts from:
CR157 Point south of Cummins Creek
CR 183 Big Creek
CR 260 200' W. of Trestle 7121
CR 435 On Walters-Noti Highway

Type B-C 1-3 II

Sub-type 2 - Division a.

G-22, Hypocrystalline, equigranular, fine-grained glassy basalts colored red through the presence of hematite.



augite (1)
anorthite (2)
glass (3)

80 diameters

Essential minerals:

Augite: 20%
0.05 mm. to 0.01 mm. granules

Anorthite: 60%
0.1 mm. to 0.5 mm. lath-shaped and tabular crystals

Accessory minerals:

Magnetite: 20%
0.02 mm. equant grains

Secondary minerals:

Hematite:
stain to the whole rock, probably due to hydrothermal alteration

Glass: 10% stained red by the presence of hematite.

Occurrence: Clarno basalt from Wasdeff Hills

Locality list:
One mile north of Lookit Damsite (Columbia River basalt)
1300' back of Wishram, Washington (Columbia River basalt)
9.3 miles from Sisters towards Creek Lake (Cascade series)
Head of Lytle Creek (Clarno basalt)

Type B-C 1-3 II

Sub-type 2. - Division b.

O-377, Hypocrystalline, equigranular, fine-grained Columbia River basalt with palagonite.

palagonite (1)
diopside (2)

80 diameters

Essential minerals:

Augite: 18%
0.1 mm. to 0.08 mm. granules

Diopside: 10%
0.1 mm. to 0.01 mm. granules

Basic labradorite: 38%
0.1 mm. to 0.8 mm. lath-shaped and crystals of tabular shape

Accessory minerals:

Magnetite: 8%
0.1 mm. to 0.2 mm. subhedral grains and aggregates of very small grains

Secondary minerals:

Chlorite: 5%

Glass:

Palagonite 20%

Occurrence: from slump from rim northwest of Clarno
Localities: 26 specimens of Columbia River basalt along the Columbia River on the south side from Middle Mountain to Maupin on the Deschutes River and on the north side from Stevenson to Chapman Creek. One specimen is from near Lyons, Oregon on the west side of the Cascades.

Type

B 1-3 V

A group of basalts which contain olivine and less than 10% magnetite. These rocks are holocrystalline, seriate porphyroid, fine to medium-grained basalts of the Madras, Intercanyon, Clarno, Cascade series and Coast Range formations.

Sub-type 1, includes 3 specimens of nearly holohyaline, scoriaceous basalt from the surface of recent flows.

Eight thin sections of the different formations were made and studied; 2 Clarno, 4 Madras and 1 Intercanyon basalts, and 1 Recent basalt from Table Rock near Medford.

The thin sections showed the rocks to be holocrystalline, fine-grained to medium-grained seriate homoid or seriate porphyroid basalts with ophitic-diabasic fabric of the groundmass or in cases of very fine-grained rocks ophitic-granulitic. Due to the constancy of the percentage of mineral constituents, no sub-types were made on the basis of granularity since the size of the crystals seem to vary with their position in the flow (central portions of each flow apparently medium-grained and the surfaces fine-grained).

Type B 1-3 V

Essential minerals.

Olivine: Occurs as a single generation and averages 9% of the rock, some specimens showing as high as 15% and others as low as 2% of euhedral to anhedral crystals; the perfection of shape depending upon the amount of alteration.

The olivine crystals include grains of magnetite, and in most cases are badly fractured, the crystals sometimes indented along the fracture lines showing resorption by the magma, the badly fractured ones are filled by a latter crystallization of groundmass crystals of plagioclase and augite. All evidence points to a crystallization period prior to all minerals excepting magnetite. This assumption is upheld by the finding of olivine crystals in very scoriaceous recent flows where the only visible mineral is olivine.

The olivine has very high birefringence, is colorless and non-pleochroic; it has negative elongation, positive character and parallel extinction. Extinction parallel to one of the two sets of very irregular fracture planes.

Olivine alters to iddingsite from a trace in one slide to 1% in O-274, and to a trace of limonite in the same slide.

Augite: Occurs in two generations in the Madras basalts, the first which shows an average size of 0.3 mm. anhedral crystal averaging 10% and reaching a maximum of 18%, and an average size of 0.05 mm. granules of the second generation which help make up the total of an average of 28% augite in each slide. The maximum percentage of augite found was 48% and the minimum was 20%.

Madras basalts show only a trace of chlorite altering from augite.

Clarno basalts consist of a single generation of granulitic augite which reaches a maximum size of 0.03, a minimum of 0.01 and an average of 0.03 mm. These granules make up as high as 30% of the specimen and have an average of 25%.

One specimen of Clarno basalt showed 15% of Chlorite altering from augite.

The intercanyon basalt contained 25% of very fine 0.01 granules and no crystals, very fresh appearing with no alteration.

The Recent basalt from Table Rock near Medford contained 20% of 0.05 mm. granules and 6% of 1 mm. subhedral crystals which had altered to 1% of chlorite.

Augite is of later formation than olivine since the crystals lack the highly fractured condition so common to olivine in this type. Aggregates of augite granules often surround an olivine crystal, and they contain inclusions of magnetite showing that they are younger than olivine and magnetite. The fact that augite of the first generation is ophitic to the plagioclases of the first generation and that augite granules of the second generation is ophitic to plagioclases of the second generation is proof that the augite is older than the plagioclases of their respective formative stages.

Augite is yellow to light green in color, is weak to non-pleochroic, gives second order birefringence. It shows positive character and very close to 45% extinction.

Plagioclases of Madras basalts show in slides:

O-116, a single generation of basic labradorite comprising 60% of the basalt and occurring in lath-shaped and tabular crystals which vary in size from 1 mm. to 0.3 mm. with an average size of 0.6 mm.

O-127, a single generation of medium labradorite, making up 60% of the basalt and occurring as 1 mm. long gulmophyric lath-shaped crystals.

O-261, a single generation of acid labradorite comprising 58% of the total constituents of the basalt and occurring in 0.2 mm. lath-shaped crystals.

O-253, has two generation of plagioclase, the first generation consisting of 15% of basic labradorite in 0.5 mm. to 1 mm. lath-shaped crystals and a second generation of medium labradorite which makes up 45% of the rock and occurs as 0.3 mm. to 0.06 mm. lath-shaped and tabular crystals.

Clarno basalt: Clarno basalts are made up of a single generation of fine plagioclases. O-312 contains 58% of lath-shaped and tabular crystals which average 0.4 mm. in length and O-274 contains 53% of acid labradorite in very fine 0.05 to 0.01 mm. lath-shaped crystals.

Intercanyon basalt: (O-209) A single specimen composed of 22% of highly fractured and resorped 2 mm. crystals of anorthite of the first generation and 40% of 0.3 mm. lath-shaped and tabular crystals of basic labradorite making up the second generation plagioclases

The Recent basalt from Table Rock shows two generations of plagioclase, the first generation consists of 15% of 0.6 mm. to 1 mm. lath-shaped crystals of basic labradorite and the second generation is made up of 30% of 0.6 to 0.01 lathshaped crystals of acid labradorite.

The presence of two generations of plagioclase indicate an unstable condition of the magma at the time of solidification and an interaction of the still fluid magma with the crystalline portion to form the second generation plagioclases as a consequence the first generation plagioclases of this type are invariably highly fractured, resorbed and the fractures are filled with glass. The assumption that the magma was still fluid is upheld by the fact that the crystals are bent and fractured and show strain shadows. Since the first generation of plagioclases occur along with highly fractured olivine and augite crystals it is reasonable to conclude that they were all formed at the same stage of solidification. However, the plagioclases are youngest of the three minerals since they are invariably ophitic to the first generation augite which as has been shown is younger than olivine.

Basalts with a single generation of plagioclase indicate a stable magma with little or no reaction between the crystalline material and the fluid. The plagioclases as a consequence are well formed, very fresh appearing and show a diabasic-ophitic or a ophitic-granulitic fabric according to the size of the grains. Diabasic-ophitic fabric is typical of the Madras basalts while the granulitic ophitic fabric is typical of the clarno basalts.

Accessory minerals:

Magnetite: Is common to all slides, varying from 1% to 8% with an average of 4%, occurring in granules, equant grains and aggregates of granules ranging in size from 0.5 mm.

Fayalite(?): Slide C-261 shows an inclusion of colorless olivine within an olivine crystal. The fayalite has a very high relief is highly fractured and occurs in the very center of the olivine crystal. It represents what remains of an iron-olivine (fayalite) crystal that has been resorped by the magma and has been replaced by chrysotile (iron-magnesium olivine) which surrounds it.

Secondary minerals:

Chlorite: Occurs in earthy masses and as stain of dull green to light yellow color in thin section and yellowish-green in hand specimen. It is secondary to solidification of the mass since it discolors minerals in contact with augite with a green stain and occurs commonly along fracture planes and lines vesicles or cavities of rock unprotected from weathering processes.

Iddingsite: Pseudomorphic after olivine, and occurs typically along weathered portion of rocks but also in the central portions where it is surrounded by minerals which have suffered little or no alteration, it is quite possible that this mineral represents a hydrothermal alteration. Iddingsite is of red color to brown color, is pleocroic; shows good 100 cleavage, negative character, positive elongation, and has strong birefringence.

Hematite: Only a trace in specimens studied. Occurs as deep red stain adjacent to larger magnetite crystals which occur near to the weathered portion of the rock. It is purely a secondary mineral in the slides studied.

Type B 1-3 V

Genesis:

Due to the fact that magnetite is found disseminated throughout the rock as a whole and is found as inclusions in olivine and augite it is undoubtedly the first mineral to form. Magnetite was followed by olivine, augite and plagioclase of the first generation. Olivine is clearly the oldest as it is badly fractured and contains augite in the fractures (in some instances). Augite is older than plagioclase since it occurs as inclusions in plagioclase and also forms ophitic fabric with it. These three minerals are all fractured, resorbed to some extent and the plagioclases show strain shadows and zonal growth.

The second generation of plagioclases crystallized following the granulitic augite with which it forms a granulitic-ophitic fabric. These minerals are much smaller, fresher and show sharper boundaries than the first generation crystals. The plagioclases are slightly more acid and show no resorption while the augite shows less alteration to chlorite than does the first generation of the mineral.

Type B 1-3 V

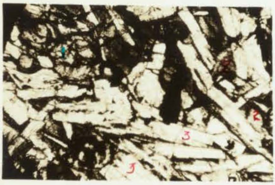
Madras Basalts: 19 specimens of Madras basalt from type localities in north central Oregon were studied; 9 of these specimens were vesicular. 3 vesicular specimens had the vesicles filled with a clear, irregular rounded masses of opal, a colorless, isotropic mineral with an index of 1.43. Of the other vesicular specimens, 3 had their vesicles filled with an earthy, isotropic mineral with an index of 1.40, which was determined as earthy opal.

The Madras basalts are very fresh, very slightly altered basalts with an average specific gravity of 2.7. They rarely show good cleavage and the fracture is very irregular to massive. Occasional phenocrysts of a reddish-brown olivine with a sub-metallic luster may be noticed which rarely exceed 1 mm. in sub-rounded crystals. The ground mass is laths of labradorite which reach a maximum length of 0.75 mm. and are visible as light colored, striated plagioclases. The augite is so intimately mixed with the plagioclases that it is unrecognizable except as a dark matrix. Very little weathering may be noticed on any of the Madras basalt.

Type B 1-3 V

Madras Basalt:

Specimen O-116, a typical specimen of Madras basalt showing a single generation of plagioclase.



olivine (1)
augite (2)
basic labradorite (3)

80 diameters

Essential minerals:

Olivine: 7%

0.8 mm. subhedral crystals slightly fractured and resorped

Augite: 30%

aggregates of granules to 0.3 mm. with a few 0.01 mm. granules included in the plagioclase.

Basic labradorite: 60%

very fresh appearing lath-shaped and tabular crystals varying from 1 mm. to 0.5 mm. in length.

Accessory Minerals:

Magnetite: 3%

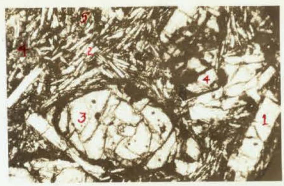
0.3 mm. anhedral crystals and 0.1 mm. equant grains

Occurrence: Flow basalt from 1 mile, above where the Metolius River turns north, above its mouth.

Type B 1-3 V

Madras Basalt: C-263, a typical specimen showing two generations of plagioclase and augite, with the second generation of plagioclases occurring in small laths which align themselves parallel to the faces of first generation crystals.

basic labradorite (1)
medium labradorite (2)
olivine (inclusion of magnetite) (3)
augite crystals (4)
augite granules (5)



80 diameters

Essential minerals:

Olivine: 18%
euhedral and subhedral phenocrysts varying in size from 1 mm. to 0.7 mm.

Augite: 15%
few crystals of euhedral form of the first generation with a maximum size of 0.5 mm. the rest 0.01 granules which make up the second generation of augite

Basic labradorite: 15%
first generation plagioclase, lath-shaped crystals with an average size of 0.6 mm. The larger crystals are fractured, slightly resorped and show strain shadows. The crystals of this generation are aligned with a subparallel relationship to each other.

Medium labradorite: 43%
second generation plagioclase occurring as lath-shaped crystals varying from 0.3 mm. to 0.05 mm. in length. These crystals are very fresh appearing, have suffered no alteration or resorption. They show a definite parallel arrangement with each other which corresponds to the face of the larger crystals which they surround.

Accessory minerals:

Magnetite: 2%
occurs as inclusions in olivine and as very small fine 0.01 mm. grains

Secondary minerals:

Limonite: Trace
alteration from olivine

Chlorite: trace
alteration from augite

Occurrence: Sec. 22, T. 11S., R. 12E.

Type B 1-3 V

Clarno Basalts:

The 12 specimens of Clarno basalt studied were collected from Coyote Creek, Grizzly, Bennett Cove and the area east of Prineville. These basalts are dense black to grayish-black with a maximum of 7% phenocrysts, of red olivine, which do not exceed 1 mm. in rounded or sub-rounded grains. They show a maximum specific gravity of 3.01 and a minimum of 2.6 with an average of 2.8. These basalts are easily distinguished from the Madras basalts by their very irregular fracture and slaty cleavage. Only one vesicular specimen is included in this type.

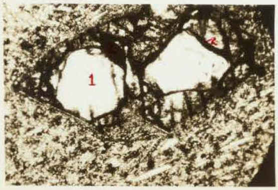
Weathering is more common in the Clarno basalts than in any other basalt of this type, it takes place on the exterior portions of the rock and follows the cleavage traces, leaving reddish yellow color from the alteration of magentite to hematite which gives the red stain and from the alteration of augite to chlorite which gives the yellow color.

In very dense specimens no plagioclases are apparent in the groundmass, but in some of the basalts they are visible as small striated laths with a maximum length of 1 mm. The vesicular specimen is the only Clarno basalt in which the plagioclases reach a maximum length of 2 mm.

Type B 1-3 V

Clarno Basalts:

O-274, typical clarno basalt showing porphyritic character of olivine crystals imbedded in a matrix of a very fine-grained, holocrystalline groundmass composed of a single generation of acid labradorite and granulitic augite.



badly altered and resorpted olivine crystal (1)
iddingsite (2)

80 diameters

Essential minerals:

Olivine: 18%
1 mm. euhedral to subhedral crystals some of which are badly fractured, altered and resorped

Augite: 30%
0.03 mm. granules

Acid labradorite: 53%
occuring as 0.08 to 0.01 mm. lath-shaped crystals

Accessory minerals:

Magnetite: 1%
0.05 mm. equant grains

Secondary minerals:

Iddingsite: 1%
pseudomorphic alteration product after olivine deep red areas showing strong pleochroism

Chlorite: trace
alteration product of augite

Occurrence: Flow north of Grizzly.

Type B 1-3 V

Intercanyon Basalts: 6 specimens of this formation were studied. They were collected from the Metolius River, Deep Canyon, Fryrear Butte, and from the Cline Falls localities. All specimens have a tendency toward a cellular structure, three are vesicular. There is no filling material in the vesicles.

The Intercanyon basalts are noticeable for their freshness, light-gray-black basalts which include very fresh light green olivine crystals with a maximum size of 3 mm. and an average size of 2 mm. These basalts show very irregular to massive fracture and have a specific gravity of near 2.7. They may be distinguished from the Madras and Clarno basalts by their conspicuous absence of weathering and alteration.

Type B 1-3 V

Intercanyon basalts:

O-209, typical specimen of Intercanyon basalt showing two generations of basic plagioclases and of augite. A seriate-porphyroid, holocrystalline, medium-grained basalt.

anorthite (1)
basic labradorite (2)
olivine (3)
iddingsite (4)

80 diameters

Essential minerals:

Olivine: 5%
0.5 mm. anhedral crystals, fractured, resorped and altered to iddingsite

Augite: 25%
1% 0.3 mm. anhedral crystals 24% of very finely granules augite

Anorthite: 22%
2 mm. slightly fractured tabular crystals showing zonal growth, and albitic twinning

Basic labradorite: 40%
lath-shaped and tabular crystals averaging 0.3 mm. in length

Accessory minerals:

Magnetite: 8%
0.05 mm. equant grains

Secondary minerals:

Iddingsite: Trace
altering from olivine

Occurrence: In Deep Canyon east of Fryrear Butte at 3200'.

Type B 1-S V

Recent Basalts: These basalts are very similiar to the Intercanyon flows; a dense, gray to gray-black and steel gray basalts with pheno-crysts of glassy green olivine with an average of 2 mm. in size.

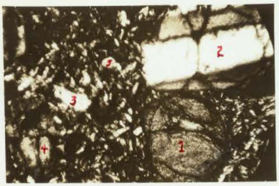
The 7 recent basalts were collected from the Three Sisters region, from Sentinel Ridge, from near Detroit on the west side of the Cascade mountains and from Table Rock near Medford, Oregon.

The type also includes 3 dike rocks from Sawtooth mountain and Salmon Creek in the vicinity of Mt. Hood and 1 specimen taken from a boulder included in the Rhododendron conglomerate in the same general region. All show the characteristic features of this type.

Type B 1-3 V

Table Rock:

Holocrystalline, seriate porphyritic, fine to medium-grained basalt with two generations of plagioclase and augite.



olivine (1)
basic labradorite (carlsbad twinning) (2)
acid labradorite (3)
augite crystals (4)
augite granules (5)

80 diameters

Essential minerals:

Olivine: 7%
0.8 mm. subhedral badly fractured crystals, showing slight resorption and alteration

Augite: 26%
6% anhedral crystals to 0.7 mm.
20% very fine 0.01 mm. granules

Basic labradorite: 30%
0.6 mm. to 1 mm. lath-shaped and tabular fresh appearing, slightly fractured crystals, comprising the first generation of plagioclase

Acid labradorite: 30%
0.08 to 0.01 mm. very fine lath-shaped crystals of the second generation

Accessory minerals:

Magnetite: 6%
0.05 to 0.01 equant grains mixed intimately with the groundmass and occurring as inclusions in olivine and augite crystals

Occurrence: Flow of upper Table Rock, near Medford.

Type E 1-3 V

Sub-type 1.

Nearly holohyaline, scoriaceous basalts from the upper portions of Recent flows. These rocks show the presence of light glass green phenocrysts of olivine (about 2% of the rock). No thin sections were made of this type.

Localities: Cinders from the top of Mt. Tabor, Portland.

3819 Scoriaceous basalt from T's Remnant.

S 8 McKenzie flow at Belknap Crater.

Type

C 1-3 V

Megascopic separation of this type from Type B 1-3 V is difficult since there is very little difference between them. Their external appearance is somewhat different, the rock being a little darker in color which gives it a denser, more basaltic character. However, the average density of both types is the same. Thin sections made of this type show that the percentage of afeloid minerals is much higher than in type B 1-3 V, and the percentage of feloid minerals correspondingly lower.

	Plagioclase	Magnetite	Olivine	Augite	Diopside	Afeloid Total
Type B 1-3 V	59%	4%	9%	28%	0	41%
Type C 1-3 V	47%	5%	15%	25%	8%	53%

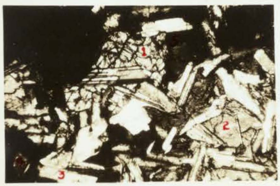
The general microscopic character of this type is identical except in the occurrence of diopside (colorless augite). Diopside occurs side by side with augite differing from it only in its optical properties. Diopside is colorless, has lower birefringence than augite, shows 38° to 40° extinction, positive character and is non-pleochroic.

Sub-type 1 of this group includes those basalts which show a high percentage of alteration of augite to chlorite.

Type G 1-3 V

Madras Basalts:

O-23, characteristic madras basalt showing a single generation of plagioclase and granulitic augite. Holocrystalline, seriate-homoid, ophitic-diabasic, medium-grained.



augite (1)
diopside (2)
basic labradorite (3)
olivine (4)
iddingsite (5)

80 diameters

Essential minerals:

Olivine: 20%
3 mm. to 0.2 mm. badly fractured and altered anhedral crystals
Augite: 10%
0.1 mm. to 0.05 mm. granules
Diopside: 20%
0.1 mm. to 0.05 mm. granules
Basic labradorite: 43%
1 mm. maximum length of lath-shaped and tabular crystals

Accessory minerals:

Magnetite: 2%
0.1 mm. to 0.05 mm. equant grains and irregular crystals

Secondary minerals:

Iddingsite: 5%
pseudomorphic after olivine

Genesis: See type B 1-3 V

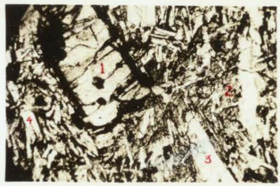
Occurrence: 2100' at the top of Circle Mesa

Type C 1-3 V

Madras Basalt:

C-285, a typical Madras basalt with two generations of plagioclase and augite; a holocrystalline, seriate porphyritic, diabasic-ophitic basalt.

magnetite inclusions
in olivine (1)
augite granules (2)
basic labradorite (3)
medium labradorite (4)



80 diameters

Essential minerals:

Olivine: 20%
1 mm. subhedral and euhedral crystals slightly fractured and altered.
Augite: 34%
6% anhedral 0.3 mm. crystals
28% 0.1 mm. granules
Diopside: 2%
0.3 mm. subhedral crystals
Basic labradorite: 10%
tabular and lath-shaped crystals with an average size of 0.7 mm. in length
Medium labradorite: 20%
lath-shaped crystals with a maximum length of 0.5 mm.

Accessory minerals:
Magnetite: 8%
0.1 mm. equant grains

Occurrence: at 3220', on rimrock on the slope of north slope of Stearn's Butte.

Localities List:
Localities of Madras basalts characterized by C-23 and C-288:
11 Madras basalts from the Warmsprings Indian Reservation, along the Metolius and White rivers and from the Madras area between Sisters and Bend. Specimens of the last area are from Upper Madras or post-Madras flows.

Type C 1-3 V

Clarno Basalts: No thin sections were made of Clarno basalts of this type the character of the rock being such that there was no doubt as to the fact that the basalts belonged in this grouping. The basalts are very dark, dense and fine-grained with small phenocrysts of reddish olivine which do not exceed 1 mm. in size and do not constitute over 15% of the rock.

With these basalts have been incorporated some basalts from Bonneville and Eagle Creek of Eocene or earlier age, that are very similiar to the Clarno basalts.

Locality List:

C-281 Clarno basalt from the head of Lytle Creek

C-298 Clarno basalt from the mouth of Sanford Creek at 3950'

C-310 Clarno basalt from the mouth of Bear Creek

BB328a Bonneville basalt 15' above the Columbia River at Bonneville

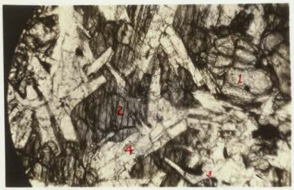
BB328b Bonneville basalt 15' above the Columbia River at Bonneville

BB329b West end of Eagle Creek at Highway Bridge.

Type C 1-3 V

Intercanyon Basalts:

O-352, Intercanyon basalt showing two generations of plagioclases and augite. A holocrystalline, seriate porphyroid, fine-grained, rock with ophitic-diabasic fabric.



olivine (1)
augite (2)
medium labradorite (3)
anorthite (4)

80 diameters

Essential minerals:

Olivine: 10%
O.7 mm. to 1 mm. badly fractured subhedral grains which include crystals of Magnetite

Augite: 30%
large irregular areas of typical ophitic nature to the plagioclases, these areas average 1 mm.

Diopside: 10%
similiar occurrence to augite

Anorthite: 10%
1 mm. lath-shaped and tabular crystals, some of which are badly fractured, show zonal growth and strain shadows

Medium labradorite: 38%
O.4 mm. to O.5 mm. lath-shaped crystals

Accessory minerals:

Magnetite: 8%
O.1 mm. equant grains and aggregates of grains in O.5 mm. laths

Genesis: see type B 1-3 V

Occurrence: at McKenzie Highway Bridge above Tumalo at 3400'

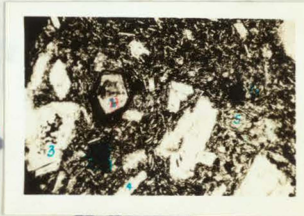
Localities: 15 specimens from an extensive area of Intercanyon basalts from Bend to Lower Bridge, Oregon.

Type U 1-3 V

Recent Basalts:

S608, Holocrystalline (with 4% glass), seriate porphyritic, ophitic-granulitic, fine-grained. Recent basalt very similiar to Intercanyon basalts:

olivine (1)
iddingsite
anorthite(glass inclusions (3)
medium labradorite (4)
augite (5)
magnetite (6)



80 diameters

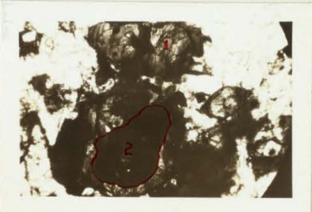
Essential minerals:
  Olivine: 15%
    1 mm. subhedral to anhedral crystals badly fractured and altered to iddingsite
  Augite: 20%
    0.01 mm. very fine granules
  Anorthite: 38%
    1 mm. to 1.5 mm. crystals showing zonal growth with the outer zones slightly more acidic than the central ones
  Medium labradorite: 10%
    0.1 to 0.2 mm. lath-shaped crystals
Accesso ry minerals:
  Magnetite: 6%
    0.1 to 0.05 mm. equent grains which occur commonly as aggregations around olivine.
Secondary minerals:
  Iddingsite: trace
  Chlorite: 4%
    alteration product of augite
Glass: 4%
Occurrence: 2 miles northeast of Broken-Top Plateau.

Localities:
  4 Recent basalts from Todd Lake, O'Dell Lake, Broken-Top Plateau and 1 basalt from Nelson Creek Bridge (Cascade series).

Type C 1-3 V

Sub-type 1.

C-607, a holocrystalline, seriate porphyritic, fine-grained basalt showing a high degree of weathering and alteration, of augite to chlorite (20%). This specimen is taken from a Columbia and Satsop gravel locality and listed as Columbia basalt. Here it has been changed to a Madras due to the characteristic madras texture and the presence of olivine. Its high degree of alteration is probably due to continued stream action, as the specimen is rounded as if it had been carried by streams and deposited in the Satsop gravels.



chlorite (1)
iddingsite (2)

80 diameters

Essential minerals:
- Olivine: 10%
  - 1.5 to 0.5 mm. euhedral and subhedral crystals showing a high degree of alteration, much fracturing and resorption
- Augite: 15%
  - 5% of 2 mm. to 0.5 mm. anhedral crystals badly altered
  - 10% of 0.2 mm. granules ophitic to second generation plagioclase
- Diopside: 10%
  - a very few large irregular areas and 0.2 granules
- Basic labradorite: 40%
  - 1 mm. to 0.5 mm. lath-shaped crystals and 0.2 mm. tabular crystals

Accessory minerals:
- Magnetite: 3%
  - 0.2 mm. long lath-like aggregations of grains and 0.01 mm. equant grains

Secondary minerals:
- Iddingsite: 2%
  - pseudomorphic after olivine
- Chlorite: 20%
  - alteration product after augite, leaves a green stain on adjacent minerals especially the plagioclase.

Occurrence: On Hood River 1 mile above Columbia Highway Bridge.
Localities: 4 specimens of basalt from Bonneville, Hecota Head and from near Clarno, Oregon.

Type

B-C 4-6 II

This type consists of a group of hypocrystalline basalts composed of intermediate-basic plagioclases, hypersthene or hornblende and very small percentages of magnetite (av.2%). The presence of hypersthene and hornblende and the absence of olivine makes a very distinctive grouping for these rocks. Bordering on andesites these rocks are probably a hypocrystalline variety of trachydolerites.

Megascopically they have a very porphyritic appearance, the phenocrysts of plagioclases seem to be badly weathered and in some cases lack the striations so common to unaltered plagioclases. The phenocrysts of the ferromagnesium minerals are not apparent, since they blende into the dark vitreous-appearing glassy groundmass.

Microscopic examinations show the basalts to contain an average of 18% glass; seriate porphyroid, medium to coarse-grained phenocrysts in a fine-grained, glassy groundmass showing fluidal fabric of the second generation plagioclases.

The high percentage of glass which gives the rock a dull black, vitreous appearance makes it impossible megascopically, to definitely place this group in either the "B" or "C" groups. Microscopic study shows feloids varying from 38% to 65% in very similiar appearing rocks. It has been thought adviseable to group these basalts in a type which would include both those with a high percentage of feloids and those with a low percentage.

Type B-C 4-6 II

Essential minerals.

Basaltic Hornblende (2%):was found only in one slide (O-530). The hornblende occurred as 0.2 mm. lath-like crystal altered to a trace of limonite. It contained inclusions of magnetite, was surrounded by augite and several very small pieces were included in plagioclase, first generation crystals. Optically, the mineral showed very strong pleochroism, brown colored with distinct cleavage, positive elongation, negative character and -12° extinction.

Hyperethene: slides contained hypersthene ranging from 1% to 15% with an average of 10% in euhedral and subhedral crystals of lath and tabular shape varying from 0.3 mm. to 1 mm. with an average length of 0.7 mm. They contain inclusions of magnetite and in some cases small crystals are included in large plagioclase phenocrysts. The mineral is of light green color, shows fair pleochroism, low birefringence, parallel extinction, negative character and positive elongation. Hypersthene is altered to 8% Bastite in two specimens.

Augite: Occurs in all slides studied, crystallizing in two distinct generations making up an average of 15% of the rock. The first generation occurs as subhedral and anhedral crystals averaging 0.3 mm. in size with a total average percentage of 5%. The second generation occurs as granules to 0.1 mm. in size with a total average percentage of 10%.

Their relation to the rest of the minerals is similier to that studied in previous types. 5% of alteration to chlorite was observed in one slide and a trace in all others.

Plagioclases: Occurs in two generations and make up percentages varying from 35% to 68% with an average of 50%. The group is marked by its difference in size, character, and form between the first and second generation. The first averages 1mm. and reach a maximum of size of 3 mm. in crystals showing resorption, alteration to kaolin to a small degree, very fine zonal growth and other indications of age, while the second generation is composed of very fine lath-shaped crystals averaging 0.08 mm. in length; very fresh appearing with no alteration of resorption and containing minute particles of the second generation of granulite augite.

The noticeable feature of these rocks is the fact that in three slides studied the first generation plagioclases were made up of medium labradorite and the second generation of andesine, while in two slides, the first generation was made up of andesine and the second of oligoclase. The only occurrence of oligoclase noted in any of the thin section studied.

The only determination possible of the microlitic laths of oligoclase was based on $\pm 0^{\circ}$ extinction on fine albitic twinning and $-2\frac{1}{2}^{\circ}$ on longitudinal sections.

Accessory minerals:

Magnetite: Maximum of 3%, a minimum of 1% and an average of 2%. Occurs as 0.05 to 1 mm equant grains with an average size of 0.07 mm.

Secondary minerals:

Hematite: Trace in (C-363) the only occurrence noted. Alteration product of magnetite in form of red stain.

Bastite or Antigorite(?): Purely secondary to the formation of hypersthene from which it alters although it may be a hydrothermal magmatic alteration and not be secondary to the solidification of the mass. Optically it occurs as pseudomorphs of hypersthene: fibrous appearance, parallel extinction; reddish-yellow color, alters to limonite at the borders.

Limonite: Appears as stain and pseudomorphs after hypersthene in this group. Alteration is secondary to solidification of the magma and occurs as yellow to brown-black earthy masses or stain with no optical properties.

Chlorite: A secondary alteration product of augite. Occurs in very small percentages in all slides studied as a light green-yellow dust or stain on the resorpted edges of augite crystals.

Kaolin: Dust like particles on the surface of plagioclases. No optical properties.

Glass:

The matrix or residual mass left after the crystallization of the second generation plagioclases. It occurs in irregular, isotropic areas with a maximum percentage of 28% and an average of 15%.

Amygdaloidal minerals:

De297 is an amygdaloidal basalt with cavities filled with clear opal with, in many cases, earthy opal surrounding the clear opal, giving it an earthy appearance.

E834 has very irregular vesicles filled with a white chalcedony-like opal, which in a few places has a very porous appearance and is stained with limonite. Material determined as earthy opal, isotropic, index 1.38- to 1.40.

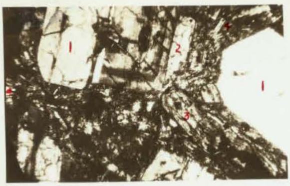
Type B-C 4-8 II

Genesis:

These trachydoleritic, hypocrystalline andesine-basalts represent flows coming from magmas of intermediate acidic-basic chemical composition. This fact is illustrated by the absence of the basic olivine and the presence of hypersthene, in one instance a small percentage of hornblende, and the presence of acid-basic plagioclases. The phenocrysts are made up of the ferromagnesium minerals which crystallized in order, magnetite, hornblende, hypersthene and crystalline augite followed by the more basic plagioclases of the rock, medium labradorite in some, andesine in others (see rock descriptions). The plagioclase phenocrysts show excellent zonal growth, the outer growths with smaller extinction angles indicating a less basic character than the inner portions. After the crystallization of the phenocrysts they underwent resorption and alteration by reacting with the still fluid magma in which they were floating. Indications of this are, a high degree of fracturing, glass inclusions, and resorption rings around the plagioclases. The material derived from the reaction of the magma with its crystalline parts enabled the formation of the second generation of plagioclases and granulitic augite. The plagioclases of the second generation aligning themselves in the direction of the movement of the flow forming the trachytic fabric so common in this type. The material left after the last crystallization stage formed the residuum of glass.

Type B-C 4-6 XI

De353. Hypocrystalline, seriate porphyroid, medium-grained Clarno basalt with hypersthene, medium labradorite and andesine.



medium labradorite (1)
(zonal growth)
hypersthene (2)
bastite (3)
andesine (4)

80 diameters

Essential minerals:

Hypersthene: 10%
1 mm. lath-like fractured crystals and highly altered to 5% bastite

Augite: 10%
mostly 0.1 mm. granules with a few 0.8 mm. crystals badly altered to 5% chlorite

Medium labradorite: 25%
2 mm. to 0.5 mm. lath-shaped and tabular crystals fractured and altered to a trace of kaolin

Andesine: 34%
0.05 to 0.2 mm. lath-like crystals

Accessory minerals:

Magnetite: 1%
very fine 0.01 granules

Secondary minerals:

Bastite: 5%
Chlorite: 5%
Kaolin: trace

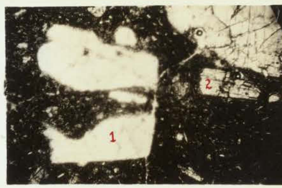
Glass 10%

Occurrence: Rim rock ½ mile west of Trout Creek, Sec.18, T.9S., R.17E.

Type B-C 4-6 II

Dc343, A typical hypocrystalline, medium-grained, seriate porphyroid Clarno basalt containing hypersthene, andesine and oligoclase.

andesine (1)
(nearly completely
resorpted)
hypersthene (2)



80 diameters

Essential minerals:

Hypersthene: 15%
0.7 mm. to 1 mm. euhedral to subhedral tabular crystals

Augite: 12%
7% 0.5 mm. anhedral crystals
5% 0.1 mm. granules

Andesine: 30%
2 mm. tabular crystals, showing high degree of resorption, inclusions of glass, zonal growth

Oligoclase: 17%
0.01 to 0.06 mm. lath-shaped crystals

Accessory minerals:

Magnetite: 1%
0.07 to 1 mm. irregular grains

Glass: 25%

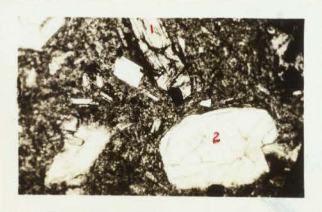
Occurrence: flow, north of Ochoco Dam

Localities: The clarno basalts represented by Dc343, Dc385 include 6 specimens collected from localities near Prineville and 2 specimens from near the Brogan Ranch in the Antelope-Ashwood area.

Type B-C 4-6 II

Madras Basalts:

C-530, Hypocrystalline, seriate porphyritic, medium-grained with fluidal fabric of groundmass, containing basaltic hornblende and hyperstheme.



basaltic hornblende (1)
medium labradorite (2)

80 diameters

Essential minerals:
Basaltic hornblende: 2%
0.2 mm. lath-shaped crystals altering to a trace of limonite
Hypersthene: 2%
0.4 mm. lath-shaped crystals of subhedral outline
Augite: 22%
10% anhedral crystals 0.8 mm to 0.2 mm.
12% granules to 0.1 mm.
Medium labradorite: 30%
badly fractured tabular crystals to 2 mm. which show zonal growth altered to a trace of kaolin
Andesine: 30%
fine 0.2 mm. lath-shaped crystals
Accessory minerals:
Magnetite: 2%
0.05 equant grains
Secondary minerals:
Kaolin: Trace
Chlorite: Trace
Glass: 11%
Occurrence: Float from Smock Prairie
Localities: 8 specimens of Madras basalts from Mill Creek, Chenowith Creek and Long Butte and Smock Prairie all of which are confined to the upper Madras or lower Cascade Series flows.

The collection also included 6 specimens of Recent basalts from near the Husband, Bridge of the Gods, Lava Falls, at Odell Lake and a recent flow on the west side of the Cascades at McCredie.

Type

B 4-6 VII

This type comprises 5 specimens of Coast Range basalts described by Callaghan (1927 U. of O Thesis) under specimen numbers Cr 162 and Cr 239. These basalts were given the name "Hawaiite Porphyry" and correspond to the andesine-basalt porphyries of other classifications.

These basalts are very coarse-grained, seriate porphyritic, and contain not over 8% glass. The phenocrysts make up 20% of the rock and are of andesine in long,thin radiating crystals reaching a maximum length of 20 mm. The specific gravity of this type averages 2.7.

The essential minerals are: Augite which averages 28% in 0.1 mm. granules altering to a trace of chlorite. Andesine occurs in two generations the first as long, thin radiating crystals reaching a maximum length of 20 mm. a minimum of 10 mm. and an average length of 15 mm. The second generation occurs as 0.3 mm. lath-shaped crystals. The first generation shows strain shadows but are otherwise fresh and show little difference other than size from the very fresh second generation.

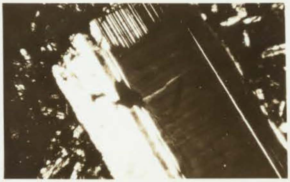
Magnetite the only accessory mineral occurs as 0.1 to 0.2 mm. equant grains and aggregates of grains in long 5 mm. lath-like forms. The maximum percentage of magnetite is 15%, the minimum 10% and the average percentage is 12%.

The only secondary minerals are a trace of chlorite and a trace of limonite from augite.

As no resorption is shown, the large crystals indicate a stable condition before the solidification of the magma. The phenocrysts were crowded and even bent by the development of gas bubbles as indicated by the strain shadows. The phenocrysts have several gradations in size without definite breaks, but it is assumed that there are at least three generations. The order of crystallization was magnetite, small feldspars and augites as these are included in the phenocrysts, and augite and plagioclase groundmass. A very small amount of glass is included. Some alteration of augite to chlorite and limonite has occurred but otherwise the rock is fresh.

Type B 4-6 VII

CR162, typical specimen of andesine-basalt porphyry, showing a holocrystalline (3% glass), seriate porphyritic, coarse-grained basalt of the Hawaiite Porphyry type (after Callaghan).



andesine

55 diameters

Essential minerals:

Augite: 29%
0.1 mm. granules

Andesine: 60%
20% of 20 mm. thin tabular crystals with excellent albitic twinning
40% of 0.3 mm. lath-like crystals

Accessory minerals:

Magnetite: 10%
small 0.2 - 0.1 mm. granules scattered throughout the groundmass. They are sub-rectangular in shape

Secondary minerals:

Limonite: 1%
as stain and replacement of augite

Chlorite: trace as light green fibrous material probably replacing augite.

Genesis: see type

Occurrence: T.16S., R.12W., Section at cave between Squaw Creek and Nancy Creek on Sea Cliff.

Type

C 4-8 VII

A very small group of fine-grained, dense, glassy steel-black colored rocks with a high specific gravity (av. 2.9) and massive fracture. These basalts are confined to the Columbia River basalt formation, 6 specimens from different localities found in the lowermost flows, and to 8 specimens of Coast Range basalts of unknown relationship to other flows.

These basalts are characterized by a high percentage of magnetite (av.18%) and the intermediate acid-basic plagioclase andesine of a single generation, barely distinguishable in the basalts as lath-like crystals with an average length of 0.2 mm.

Microscopically this group represents a hypocrystalline, fine-grained equigranular andesine-basalt (although some authors would call this type an andesite, the writer prefers the name andesine-basalt since the mineral hypersthene so common to andesites is not present).

Essential minerals.

Augite and Diopside: The typical occurrence of augite is in association with diopside, although in one slide there is no diopside present. These minerals take the form of highly irregular masses which cover 0.35 mm. areas, of the two minerals augite is predominant although very slightly so since the average of augite is 12.8% and that of diopside is 10%. The minerals occur contemporaneously with each other and were the first minerals other than magnetite crystallize since they form a typical ophitic-diabasic fabric with the plagioclase. The total average percentage of augite and dipside in the slides studied was 30%.

Andesine: A single generation of this plagioclase in all slides studied. They are very fresh, show little fracturing and no resorption, they reach a maximum size of 1 mm. in one slide with an average of 0.4 mm. in lath-like crystals, which with augite form an ophitic fabric. Andesine represents the last mineral to crystallise.

Accessory minerals.

Magnetite: Occurs as large irregular 0.12 mm. masses and smaller particles to the size of dust. It makes up an average of 18% of the rock. Magnetite was the first mineral to crystallise since it is found in inclusions in augite and as small particles thoroughly disseminated throughout the groundmass.

Secondary minerals:

Chlorite: There is a trace of chlorite in all slides occurrig as a green stain and is formed from the alteration of augite.

There is a slight trace of hematite stain on the outer portions of the basalts showing a slight alteration of magnetite.

In CR330, calcite occurs to 5% as thin 0.1 mm. veins which cut thru the rock along fracture planes.

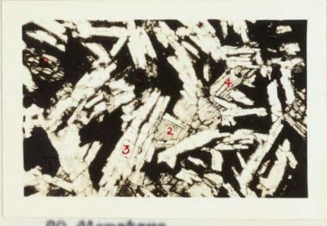
Glass:

An average of 12% in all slides studied.

Genesis: These basalts represent a flow coming from an intermediate acid-basic magma, with magnetite disseminated throughout the flow at the time of flowage. As the flow became cooler the augite crystallised as irregular areas slightly preceding andesine. The crystallisation of the total augite constituents so lowered the freezing point of the magma that there was only time for the crystallisation of a single generation of plagioclases to form and the remaining material formed glass which acted as a matrix for the minerals.

Type C 4-6 VII

C-119. A typical hypocrystalline, equigranular, fine-grained Columbia River basalt of this type.



magnetite (1)
diopside (2)
andesine (3)
augite (4)
glass (5)

80 diameters

Essential minerals:

Augite: 18%
0.4 mm. large irregular areas

Diopside: 10%
0.4 mm. large irregular areas

Andesine: 48%
0.4 mm. lath-shaped and tabular crystals, very fresh appearing unaltered or resorpted

Accessory minerals:

Magnetite: 20%
large irregular 0.12 mm. masses to particles the size of dust grains

Glass: 10%

Genesis: See under type

Occurrence: Flow, sec. 2, R.13E, T.8S; South of Skookum Creek

TABLE

Section (C-472a top; C-472q bottom).

C-472	Plagioclase	%	Augite	Magnetite	Glass
C-472a	Bytownite	40%	50%	6%	4%
b	Bytownite	40%	50%	5%	5%
c	Bytownite	61%	36%	2%	1%
d	Bytownite	57%	40%	1%	2%
e	Bytownite	53%	40%	2%	5%
f	Labradorite	58%	30%	2%	10%
g	Labradorite	40%	40%	8%	12%
i	Labradorite	40%	40%	10%	10%
j	Labradorite	45%	35%	10%	10%
k	Labradorite	45%	35%	10%	10%
l	Labradorite	40%	35%	13%	12%
m	Labradorite	40%	40%	15%	5%
n	Labradorite	30%	20%	10%	40%
o	Labradorite	45%	30%	10%	15%
p	Lab-Andesine	45%	25%	25%	5%
C-472q	Andesine	45%	40%	10%	5%

Several noticeable features were observed in the course of the petrographic study of the Tygh Valley section and numerous other Columbia River basalts which are as follows:

The first noticeable feature of the Columbia River basalts of north central Oregon is the fact that the lowermost flows were composed of the plagioclase andesine, augite and a large percentage of magnetite making the basalt an intermediate (acidic-basic) variety probably andesine-basalt. As the number of flows increase the relative basicity of the magma seems to increase until at the top the basalt is composed of basic plagioclases with augite and magnetite.

The second noticeable feature was the absence of olivine in the Columbia River basalts of north central Oregon. Whether this characteristic is widespread throughout the whole of eastern Oregon is a debateable question. It may be stated here, however, that Renick who did extensive petrographic work on the Owyhee basalts (which he correlates with the Columbia) noticed the absence of olivine in that series.

As a general feature, it may be said that the Columbia basalts can be recognised in field by their massive, fine-grained and hypocrystalline character. The holocrystalline and porphyritic types play a very subordinate role to the others. In the more nearly holocrystalline types wherein there is a large percentage of interstitial glass, (palagonite) the basalts show a rusty-red color, due not to weathering as previously considered.

The last characteristic feature of the Columbia River basalts is the high percentage of magnetite; most of the basalts falling in range VII.

Varying degrees of weathering are noticeable in the Columbia River basalts and are important since the final disintegration product of them form the valuable farm lands of different parts of the state. It has been observed that the first mineral to be weathered is augite which alters to chlorite (see types). The alteration follows along fracture lines or works inward from vesicles open to the weather (O-622). In time this weathering and alteration envelopes the whole rock to the depth of about 1/16 inch. The presence of the friable chlorite breaks down the matrix which holds the more resistant plagioclase magnetite and glass and allows the outer edge to fall off (H68, O-643). This leaves a more or less concentric core (D74). The disintegration of the resulting basalt fragments sets free the minute grains of magnetite glass and plagioclase crystals. The plagioclases kaolinize to form clay. The hydration of the magnetite forms hydrous iron which gives the characteristic red color to the soil.

This weathering process is very slow, dependent almost entirely upon the humidity of the region. On the western side of the Cascade mountains, the weathering is more pronounced and gives rise to a large part of the residual soils of that region. On the eastern side, under nearly semi-arid conditions, the weathering is slight and the soil covering is meager.

The Madras Basalts.

The Madras basalts may be distinguished from the Columbia River basalts by their fresher appearance, lighter color and by their texture. The basalts of this formation are holocrystalline, fine to medium-grained and are often seriate porphyritic. Glass never occurs in appreciable quantities. The presence of olivine in dark green and deep red colors is the striking feature of these rocks.

They vary somewhat in structure, the massive basalts of the central portion of the flows grading into a cellular structure on the uppermost portions, indicating the escape of a large amount of fugitive constituents as the rock reached its final cooling stage. On the margins of the flows the cellular structure passes into a vesicular one and commonly these vesicles are filled with opal of several varieties (see types B and C 1-3 V).

Microscopically, these basalts prove to be very basic types being made up of basic plagioclases, olivine, augite and magnetite.

The plagioclases have two typical modes of occurrence; first, as a single generation and, second, as two generations the first larger, and more basic and older appearing than the second which invariably align themselves with a sub-parallel arrangement to the faces of older crystals.

Many of the Madras basalts contain enough magnetite to place them in range VII, whether this is a characteristic of the formation or a matter of segregation is a point which will require much more exacting work.

The fabric of the basalts is ophitic in all cases. In fine-grained rocks the augite is ophitic-granulitic to the plagioclases and in coarser-grained rocks it is ophitic-diabasic to them.

Only an inference may be drawn concerning the relative basicity of the flows of this formation since no complete sections were studied or made. In one locality, Sec.22, T.11S., R.12E., (specimens O-261, O-262, O-263), the three top flows were studied and the following observations were recorded. First, that the plagioclases of the Madras basalts seem to become less basic as the number of flows increase. The top flow (O-261),consists of a single generation of acid labradorite; the second flow (O-262), a single generation of medium labradorite and the third flow (O-263), two generations, the first of basic labradorite and the second of medium labradorite. These observations (assuming them to be correct) would not support the statement that the different flows become less basic as the number of flows increase, that opinion would necessarily have to be checked by more careful and detailed work of different sections.

The second observation is that the Madras flows are all basaltic and none are andesitic as has been the opinion held for some time. Their andesitic appearance is due to the fresh, unaltered character of the rock, many of which, although appearing very light colored, are very basic basalts.

The Intercanyon Basalts.

The intercanyon basalts of north central Oregon constitute the most basic basalts of the area. They are easily recognised petrographically by the presence of fresh bottle-green olivine occurring as large phenocrysts imbedded in a very fresh, unaltered groundmass of plagioclase and augite. The plagioclases occur as long lath-shaped or tabular crystals surrounding minute dark crystals of augite. Their characteristic structure is cellular although the basalt is hard to distinguish from the Madras basalt in this character as it also grades from massive to cellular to vesicular. No fillings of opal were observed in the vesicles of the Intercanyon basalts.

The three specimens studied microscopically are from widely separated localities and show condusively that they are very basic basalts composed of anorthite as first generation plagioclases with basic to medium labradorite as the second with the other essential minerals being made up of augite and olivine. The rocks contain a small amount of magnetite. These basalts are holocrystalline, medium-grained, seriate porphyroid basalts with true ophitic fabric.

The Basalts of the Cascade Series.

Recent basalts, younger than the andesites of the Cascade series overlying the Madras basalts which are very similiar, both megascopically and microscopically, to the Intercanyon basalts of the Deschutes Plains.

The Clarno Basalts.

No conclusions may be drawn which would definitely separate the Clarno from other formations through the observations recorded in this work. The thin sections studied are from specimens from widely divergent localities and they fall in nearly every type of the classification. General observation, however, shows the basalts to be fine-grained with a higher degree of alteration than other basalts. They vary greatly in crystallinity, fabric and mineral composition one group being an andesine-basalt while the other are true basalts.

General Observations.

Combining the facts as recorded in the literature with those observations recorded in this study it may be seen that the order of magmatic flowage in north central Oregon is 1st, acidic, 2nd, intermediate-basic, 3rd, basic, 4th, intermediate-acidic and 5th, basic.

The extrusives of the Eocene Clarno formation, consisting of a large series of tuffs and rhyolites with relatively insignificant flows of the more basic basalt, followed by the great depth of oligocene tuffs of the John Day formation, make up a series of acid extrusives. These acid extrusives were followed by the great series of Columbia River basalts which grade from acidic-basic to basic in character being free of the more basic ferromagnesium minerals such as olivine and hypersthene.

Following the extrusion of the Columbia River basalts there was a period of diastrophic movement in the Pliocene which culminated in the extrusion of basic-olivine basalts of the Madras formation interbedded with large amounts of tuff. These flows were soon followed by less basic volcanic andesites of the Cascades which ranged from andesine-basalts, with olivine, above the Madras to true andesites with hornblende and hyperstheme replacing the olivine in the upper series.

After the formation of the andesites there occurred sporadic recent volcanic disturbances which formed the recent basalts of the Cascades and the Intercanyon basalts of the Deschutes Plains region. These later basalts are the most basic of the series.

It seems logical to assume that these great lava floods of north central Oregon had their origin from the same magmatic reservoir and all were extruded from the same definite lines of weakness in the earths crust which is apparently along the axis of and slightly to the east of the Cascade Range in central Oregon.

After studying the different specimens megascopically and microscopically, it is the opinion of the writer that much more satisfactory results could be obtained regarding the characteristic mineralogical features of the different formations, if more care would be used when collecting specimens. It has been recognized by petrographers for many years that in dealing with flow basalts the textural relation of the rocks varies from fine to coarse-grained and from holocrystalline to hypocrystalline in respect to the position of the basalt in the flow. The central portion being, invariably, coarser grained and more nearly holocrystalline than either of the margins. The margins often passing into a pure glassy phase or into, what is more common, a glass with a "vitrophyric structure".

The wide range in textures exhibited by the basalts of the collection seemed to bear out these contentions and the following tables (I and II) were compiled. The first listed specimen in each of the two groups indicates the normal basalt and gives the more normal percentages of minerals present.

General Observation

Table I
(C 1-3 VII, B-C 1-3 II, B-C 4-6 VII Types)

Basalts below 45% Feloids.

slide	glass	magnetite	femic	plagioclase
O-472a	4%	6%	50%	40%
H 180	6%	18%	45%	32%
O-472g	12%	8%	40%	40%
O-642	15%	10%	32%	43%
O-377	30%	5%	30%	35%
O-300	34%	12%	19%	35%
3361	39%	10%	16%	35%
O-472n	40%	10%	20%	30%
Ba F2	49%	1%	10%	40%
O-162	60%	10%	0%	30%

Table II
(B 1-3 VII, B-C 1-3 II, B-C 4-6 VII Types)

Basalts above 45% Feloids.

slide	glass	magnetite	femic	plagioclase
O-472d	2%	1%	40%	57%
Table Rock	3%	3%	34%	60%
O-382	10%	10%	30%	50%
O-472f	10%	12%	30%	43%
O-530	11%	12%	27%	60%
CR330	15%	15%	20%	50%
O-22	18%	2%	20%	60%
Do325	30%	10%	0%	60%

From a study of these tables, the assumption may be made that the normal basalt of class B and C are holocrystalline and that they grade into hypocrystalline and vitrophyric varieties near the margins of the flows in which they occur.

No definite conclusion may be formed since these specimens were not collected from the same flows. These studies show, however, that further research may prove that the gravitational factor causes the heavier afeloid minerals to sink. This loss of the afeloid minerals from the upper portion of flows lowers the freezing point to such an extent that only the plagioclase constituents are allowed to crystallize. These feldspars, being the only crystals formed, are thus imbedded in a matrix of glass (vitrophyres). Towards the central portions, there is a gradual increase of femic minerals and a corresponding decrease of glass until the holocrystalline form is reached.

With this in view, it is the opinion of the writer that the true character of the different basaltic formations of Oregon may not be determined until future workers make an extensive research on the holocrystalline basalts which would involve careful and systematic sampling of individual flows.

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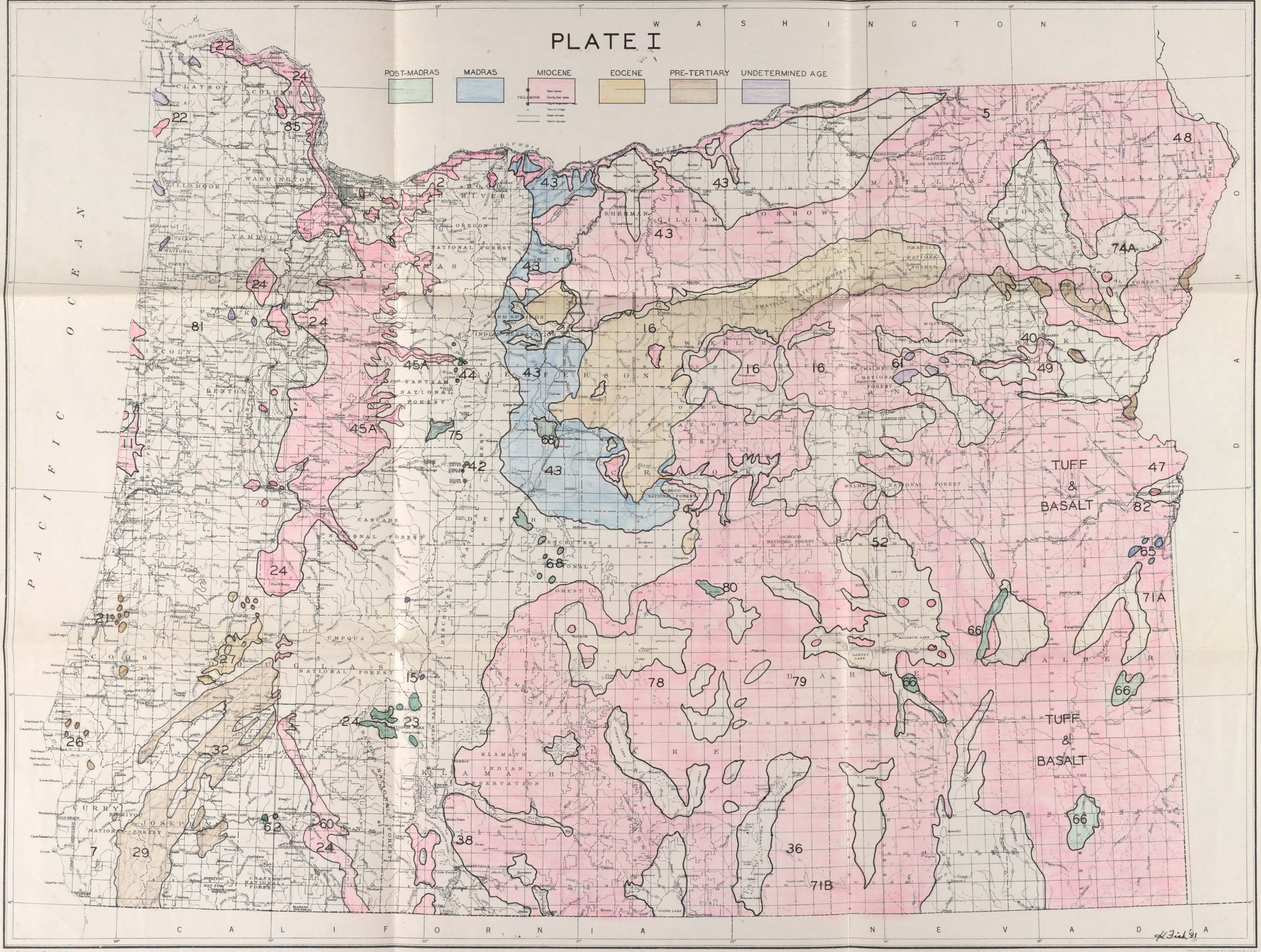
OREGON



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