SPHERULITIC BRECCIAS IN A DOME NEAR WENATCHEE, WASHINGTON

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ABSTRACT

A felsitic dome located on an anticlinal axis in the lower Eocene Swauk arkose in central Washington has partial borders of perlite and felsitic breccia. Portions of the perlite and the breccia have been converted into a mass of spherulites comprising up to 80 per cent of the volume of the rock. Chemical analyses of the spherulitic breccia, the perlite and the arkoses give clear evidence as to what has been added metasomatically to cause the transformation to spherulites. The arkose and the perlite are remarkably similar in chemical composition. The analysis of the spherulites shows that potash and silica have been added, probably accompanied by a release of water from the perlite during the course of crystallization. Brecciated margins of the dome have provided avenues of transfer for the solutions and it is in these zones that the spherulites have had their most abundant growth.

INTRODUCTION

Wenatchee is located on the west bank of the Columbia River in the geographic center of the state of Washington. The rocks in this vicinity are a series of arkoses, shales, and conglomerates, known as the lower Eocene Swauk formation, folded into a series of northwest-southeast trending anticlines and synclines. The Yakima basalts of Miocene age overlie the truncated folds of the Swauk sediments with a marked unconformity and they also form the vast Columbia Plateau on the east side of the Columbia River.

On the southern city limits of Wenatchee a dome rises 150 feet above the orchard covered terraces and forms a distinctive landmark. This dome was intruded along the axis of one of the major anticlines in the Swauk arkoses. It is the purpose of this paper to describe the rock types in this dome, to explain the origin of the rocks now converted almost wholly to spherulites and to give some evidence as to the nature of the metasomatic solutions that took part in this transformation.

As early as 1904 Smith and Calkins noticed the "Pronounced lamination more or less parallel to the surface on all parts of the dome." In 1936 Chappell mapped the Wenatchee quadrangle and again mentioned the striking jointing forming plates parallel to the periphery. He also called attention to the perlite exposed on the southeast side and to the friable sand resulting from the disintegration of portions of the perlite. As a result of Chappell's careful work the thickness of the perlite was established as approximately 50 feet, rather wide for a chilled selvage on a dome 400 feet in diameter.

The wide interest in perlite as an industrial material during the past few years has focused attention on all perlite deposits. Huntting (1949) reviewed the deposits within this state and made an investigation of the Wenatchee locality. He described a thin section from Wenatchee showing 80 per cent glass and the remainder composed of crushed quartz and plagioclase phenocrysts with a few scattered crystals of biotite and hornblende. A partial analysis of the rock and the expansion qualities were given by Huntting.

Occurrence

This dome forms but one of many intrusives located along the axis of an anticline in the Swauk arkoses and shales of lower Eocene age. In common with the major structural trends in central and western Washington this axis strikes in a general northwest-southeast direction. The intrusives vary greatly in composition along the axes of the folds in the sediments. Basalts, andesites, dacites, rhyolites and their porphyries are all represented. The more basic varieties are usually in the form of sills, dikes, or laccoliths. The more acid types are roughly circular or irregular in shape and many have been altered intensely by hydrothermal solutions.

The most striking feature of the dome is the concentric platy jointing. Sheets several feet in diameter may have a thickness of one-half inch or less. The parallelism of minerals and the distinct bands of slightly different color indicate flow banding and the platy parting is obviously parallel to the flow-banding. The sheets dip away from a common center with angles varying from 25 to 55 degrees.

The core of the dome is a white porphyritic (or xenocrystic) felsite. Along the southern margin is a rim of medium gray banded perlite approximately 50 feet thick. The northern border of the dome is rimmed by a breccia composed of gray felsitic blocks in a matrix of similar material but darker gray. Locally hydrothermal alteration is very marked. Spherulites developed in this breccia and in much of the core contiguous to the breccia. In places over 80 per cent of the rock is composed of spherulites.

Petrography and Petrology

The core is composed of a white, platy, porphyritic (or xenocrystic) felsite with crystals or pieces of quartz averaging one millimeter in diameter making up to 15 per cent of the volume of the rock. Less abundant than the quartz is plagioclase (An27) exhibiting strong zoning with more sodic rims or, if the zoning is lacking, they may be deeply embayed or almost completely replaced with spherulites. The sodic rims seemed to have served as a protection against reaction with the magma and only those with rims now have euhedral shapes.

Brown biotite and pale green hornblende are present in very small

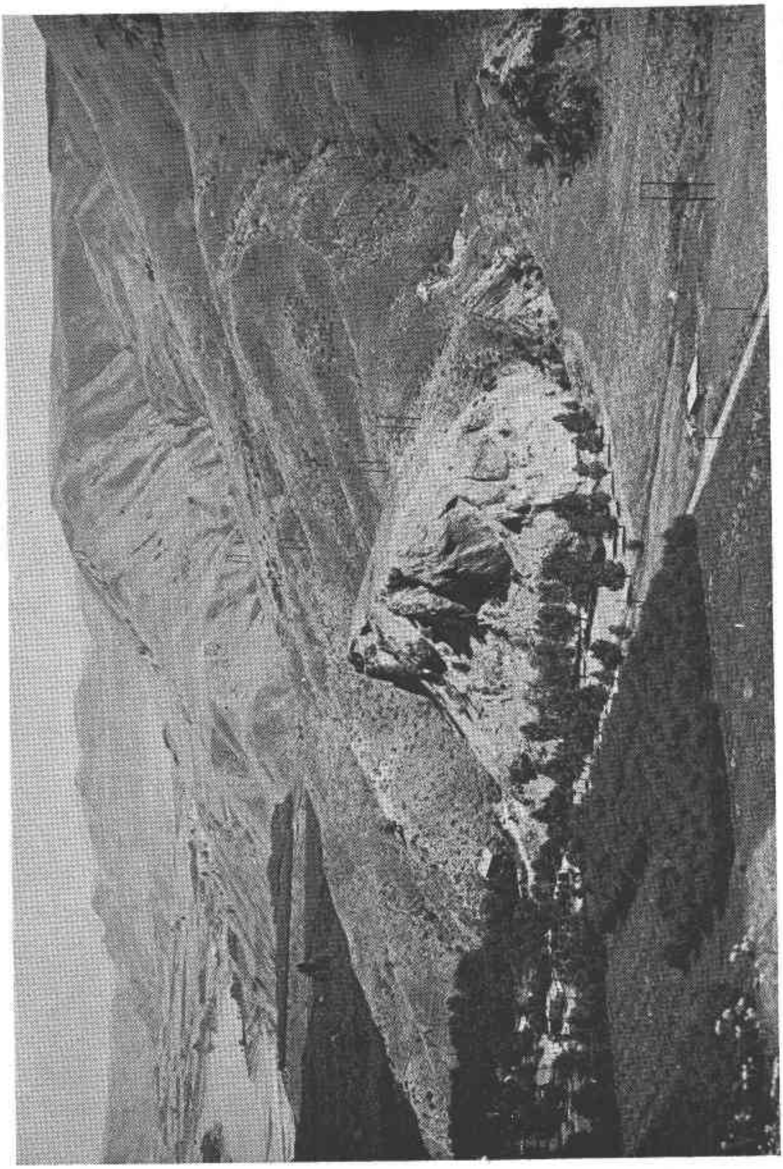

FIG. 1. The Wenatchee dome looking southeast along the anticlinal axis in the Swauk. The Columbia River is visible in the upper left. The low ridge on the right of the dome is the silicified arkose, the low ridge on the left is the quartzitic conglomerate. The perlite is partially exposed on the right side of the dome.

quantities. The quartz is peculiar in that the shapes may be sharp and jagged or they may be rounded and very deeply embayed. Such shapes are characteristic in the neighboring arkose and silicified conglomerate. Even more suggestive of the incorporation of the arkose fragments in the dome rocks is the distinctive undulatory extinction so typical of the rounded quartzite pebbles and the angular clastic grains of the arkose. Most of the quartz and some of the feldspars thus appear to be xenocrysts instead of phenocrysts. Ross (1948) found similar fragments of quartz and feldspar in a fused glass in New Mexico.

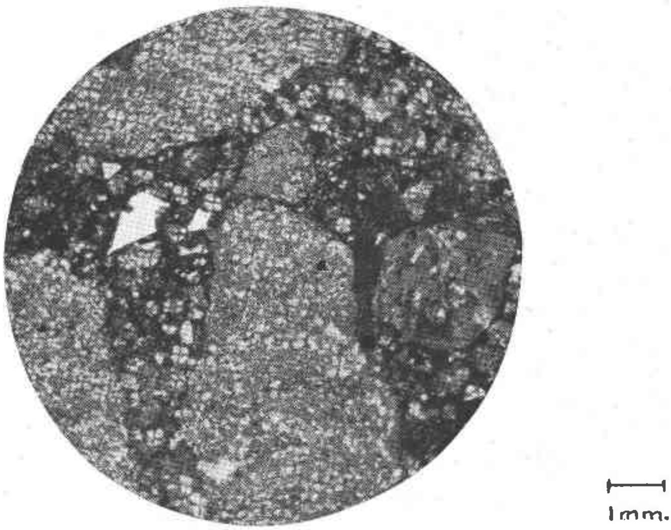

FIG. 2. Spherulitic breccia under crossed nicols. The small black crosses indicate the presence of spherulites both in the blocks and in the matrix.

The perlite where best exposed on the southern margin of the dome is a medium gray rock with alternating bands of light and dark gray material. The crystals are approximately the same size as those in the core rock but more xenocrystic. In some sections the quartz is strung out in a line of angular fragments parallel to the flow banding as in a protoclastic border. In the perlite the plagioclase is either angular or deeply embayed but does not show the addition of more sodic rims. The glass in the perlite has an index of 1.492 indicating a high silica content (73%) according to the tables by George (1924) and this is verified by the chemical analysis. Clear belonites are plentiful in the perlite and pass across the concentric cracks without interruption. Most belonites show a subparallel arrangement undoubtedly due to flowage.

The breccias are composed of light gray blocks up to several inches in diameter set in a darker gray matrix of finely comminuted fragments (see Fig. 2). The breccia is firm and brittle where late hydrothermal action has not been severe. The lighter colored blocks resemble the perlite or central core felsite under the microscope in that they are clear and charged with belonites oriented in a sub-parallel fashion. The perlitic cracks, however, are lacking. Under crossed nicols the development of spherulites is striking for they make up from 60 to 80 per cent of the rock and occur in the darker matrix as well as in the blocks.

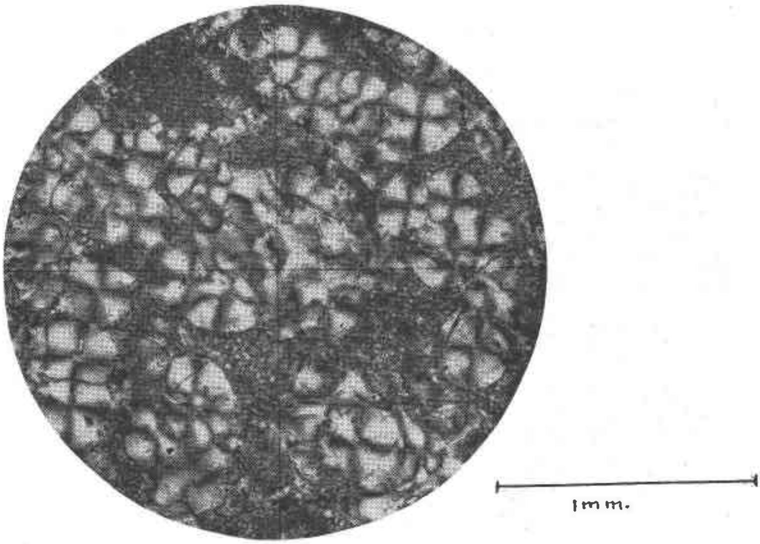

FIG. 3. Spherulites in the blocks under higher magnification and crossed nicols.

The spherulites are uniform in optical properties and each spherulite is homogeneous throughout its mass (see Fig. 3). Indices determined were $Nz=1.530$ and $Ny=1.528$. These together with the other optical properties suggests a perthitic composition for the spherulites. In his x-ray determination of sub-microscopic spherulites Hurlbut (1936) inferred that they contained perthite and cristobalite. The spherulites from Wenatchee may be very similar but quartz is present in many of the cavities. Tiny spherulites may occur between some of the larger ones but a remarkable uniformity in size exists in that most of the larger spherulites attain a diameter of 0.2 mm. In the matrix where iron oxides are more prevalent the spherulites have concentrated the iron oxides in the center of each spherulite leaving a clear, rounded rim.

The belonites still retain their sub-parallel alignment in the spherulites within the blocks in the breccia. Perhaps this is due in part to the size of the belonites for they may be as long as the diameter of the spherulite, or one belonite may lie across the boundaries and within two spherulites. This indicates the spherulites were formed after all movement had ceased and that all formed at approximately the same time. Similar evidence was used in deciphering the origin of the Yellowstone vitrophyres by Howard and Colony (1934 and 1939).

Perlite and Spherulitic Breccia. In a search through Professional Paper No. 99 (1917) for analyses of perlites, pitchstones, and obsidians all 80 examined showed a decidedly higher percentage of potash than is found in the Wenatchee perlite. Those with a relatively low potash content were also very much lower in silica. Even the soda-rhyolite of Yellowstone (Iddings, 1885) had twice as much potash as occurs in the glassy phase of the dome at Wenatchee. Most all of the obsidians were far more deficient in water. The pitchstones and perlites averaged between 3 and 4 per cent of water but the extremes were between one and 13 per cent. Thus the Wenatchee perlite is most unusual in its extremely low potash content. Less unusual is the moderately high water content.

TABLE OF ANALYSES

	1	2	3	4
SiO_2	73.33	74.11	77.30	89.95
Al_2O_3	15.27	11.20	12.39	4.94
Fe_2O_3	3.25	.52	.57	.43
FeO	.11	.28	.19	.18
MgO	.15	.23	.10	.04
CaO	.09	1.88	.68	.14
Na_2O	.09	3.17	3.14	.34
K_2O	1.38	1.04	4.36	3.10
H_2O+	5.30	5.14	.60	.43
H_2O-	.35	2.20	.31	.11
TiO_2	.70	.11	.12	.07
P_2O_5	.07	.02	.02	.02

No. 1 Arkose, Eileen H. Kane, analyst.
No. 2 Perlite, Eileen H. Kane, analyst.
No. 3 Spherulitic breccia, Eileen H. Kane, analyst.
No. 4 Silicified arkose, Eileen H. Kane, analyst.

A glance at the table of analyses shows a striking difference between the potash content of the perlite and the spherulitic breccia. Since the breccia is composed predominantly of spherulites it may be assumed that the analysis for this rock corresponds very closely to the analysis of the spherulites themselves. The chemical analysis of the spherulitic breccia is almost identical with that of the small dark blue spherulites from

Obsidian Cliff in Yellowstone National Park. If the spherulitic breccia is formed at the expense of the perlite, or possibly the glassy to cryptocrystalline material of the core, then the greatest change involved is the addition of potash to form the spherulites and the loss of water as crystallization progressed. A decrease in CaO and an increase in silica is also noteworthy.

All evidence points to the formation of the spherulites from the glassy to cryptocrystalline material of the core, or from the clear perlites. The belonites so typical of the glasses are still present in the spherulites and with approximately the same orientation. Many sections show portions of the glass partially converted to spherulites. The chemical analyses are so similar (except for the potash and water) that no doubt exists as to their common origin. A separate intrusion may be postulated for the spherulitic material but the intimate admixture with the glass precludes this possibility. All other studies in the literature of spherulites point to their growth at the expense of the enclosing glass.

The conditions of spherulitic growth have been well described by Foshag (1926).

> The solubility of silica in gaseous water may be fairly great at comparatively low temperatures. The solubility need not be great, nor the amount of solvent large for the solvent in a case such as this acts as a catalyzer. Its action is continuous. As rapidly as the crystalline phase separates from its super-saturated solution the solvent is capable of dissolving more glass, the process continuing until the transformation is complete or until the escape of solvent stops the reaction. In this manner the final effect of a small amount of solvent can well be the transformation of a considerable bulk of glass into crystalline matter.

At Wenatchee the effective solvent was potash and water, probably in the gaseous form. Locally the transformation to spherulites has been almost complete.

The brecciation so characteristic of domes, as pointed out by Williams (1931), provided a porous zone for hydrothermal solutions. As a result the strongest alteration hydrothermally and the most complete transformation to a mass of spherulites is in, or contiguous to, the zone of brecciation.

Arkoses. In dealing with instrusive igneous masses it is well to consider the country rock and its structure. Two ridges of Swauk sediments occur on either side of the dome (see Fig. 1). The one 150 feet to the east is a conglomerate composed essentially of rounded quartzite pebbles ranging from one to six inches in diameter. The larger pebbles are rounded but in thin section the smaller fragments of quartz are very angular. Most all of the quartz shows a wavy extinction. Crumpled flakes of leached biotite and muscovite are also present. This bed strikes N 50° W and dips 60° to the N.E. The ridge 200 feet to the west of the dome is a very silicified arkose striking parallel to the other ridge but dipping steeply to the southwest. The dips are not primarily due to local doming for an anticlinal axis extending for several miles passes through the dome and elsewhere along this axis the dips are steep. One would expect the ridges on either side to be bowed outward around the dome. The exposures of the ridges adjacent to the dome are not continuous and hence it is difficult to determine if bowing has occurred or not. The meagre exposures indicate that they are not definitely bowed out and certainly not sufficient to allow the emplacement of so large a dome.

Two samples of the Swauk arkose were selected for analysis. Sample No. 1 was a half mile from the dome and showed no indication of igneous or hydrothermal action. This is a buff colored arkose, quite firmly cemented but it can be broken with the fingers along the weathered outcrop. Sample No. 4 is from the ridge of silicified arkose immediately west of the dome. These samples were selected in the hope that they would give some clue as to what influence the country rock might have had on the instrusive and also what might have escaped from the intrusive into the country rock.

Most unusual is the striking similarity of the arkose some distance from the dome (No. 1) and the perlite (No. 2). The percentages of silica, potash and water are extremely close although the localities are separated by more than half a mile and one rock is distinctly sedimentary—the other definitely igneous. The higher alumina and ferric oxide content of the sediment is to be expected on a weathered surface even if the rocks originally had the same composition. One may well wonder how close the arkose would be to the perlite if fused.

Chemically they are very similar and xenocrysts of the sediment are scattered in the glass and in the core rock. In this connection it is noteworthy that $2\frac{1}{2}$ miles southeast of the dome a well was drilled on the axis of an anticline in the Swauk in the search for oil. At a depth of 821 feet below the surface the well penetrated 8 feet of perlite and 169 feet of perlite in the lower part of a 256 foot thick rhyolite body (Huntting, 1949). Of course it is unlikely that these are true thicknesses for the penetration of a drill through a body of unknown orientation could give a true thickness in only one position.

Relation of Perlite to Felsite. The relation of the perlite to the felsite is somewhat obscure. The perlites may represent chilled borders but the thicknesses are unusually large for the size of the intrusives. It is very doubtful if a perlitic border extends more than half way around the dome. They may represent separate intrusions of perlite and felsite. However, even in the well the perlite was encountered at four separate horizons in the rhyolite. The gradations between the perlite and felsite at the dome, and their striking similarity in chemical composition would be evidence against separate intrusions. As pointed out by Higazy (1950) two such rock types could exist together as differentiates from a soda rich and a potash rich magma, but not as differentiates from a common basaltic magma. As he also points out they could be formed by metasomatic processes if the field and textural studies so indicated. The field and chemical evidence at Wenatchee gives every indication that metasomatism has been operative in the vicinity of the dome and elsewhere.

These masses may be due to local fusion of the arkoses either by hot alkaline solutions or by the intrusion of the rhyolitic magma or both. The lack of needed displacement in the ridges adjacent to the dome lends support to this idea. The striking similarity in chemical composition of the perlite and the arkose, together with the fact that the perlite has a most unusual composition, is indicative of this origin. The presence of xenocrysts of the arkose in the perlite in various states of being resorbed is suggestive of some fusion or reaction. However, the evidence for the origin of the perlites is not conclusive at Wenatchee.

Origin of the Spherulitic Breccias. It is quite evident that the spherulites were formed from the perlite or glassy portions of the felsite aided by metasomatism. The silicified arkoses adjacent to the dome give some indication that silica has been added. Silica was used in forming the spherulites so none was released by the dome rocks. Silica, therefore, was probably added metasomatically and many other localities near the dome show excellent evidence of silica and alkali metasomatism (Coombs, 1950).

The potash content of the silicified arkose has increased greatly in proportion to the other oxides. All values are depressed because of the very high silica content. Potash was also used in forming the spherulites so no excess was available from the perlites. This too must have been added metasomatically. Terzaghi (1948) described and gave evidence for a very similar type of potash and silica metasomatism in the obsidians at the Esterel, France.

Water was released from the perlite during its crystallization and in all probability it too was added metasomatically. Its avenues of transfer are marked by hydrothermal alteration both within the dome and within the sediments.

Thus the spherulites at Wenatchee seem to have been formed at the expense of the glass but the process was aided considerably by potash and silica metasomatism. Water, probably in the gaseous form, may have been added but much was released during the course of crystallization of the perlite.

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REFERENCES

CHAPPELL, W. M. (1936), Geology of the Wenatchee quadrangle, Washington: *Univ. of Wash. Ph.D. thesis*, unpublished.

COLONY, R. J., AND HOWARD, A. D. (1934), Observations on spherulites: *Am. Mineral.*, **19,** 11, 515–524.

COOMBS, HOWARD A. (1950), Granitization in the Swauk arkose near Wenatchee, Washington: *Am. Jour. Sci.*, **248,** 369–377.

FOSHAG, W. F. (1926), The minerals of Obsidian Cliff, Yellowstone National Park: *U. S. Nat'l. Museum, Proc.*, **No. 2618,** 1–18.

GEORGE, W. O. (1924), The relation of the physical properties of natural gasses to their chemical composition: *Jour. Geol.*, **32,** 353–372.

HIGAZY, RIAD A. (1950), Significance of the orthoclase-albite-anorthite, and the $NaAlSiO_4 \cdot KAlSiO_4 \cdot SiO_2$ equilibrium diagrams in igneous petrogeny: *Am. Mineral.*, **35,** 11 and 12, 1039–1049.

HOWARD, A. D. (1939), Layering in Yellowstone rhyolite: *Jour. Geol.*, **XLVII,** 6, 658–664.

HUNTTING, MARSHAL T. (1949), Perlite and other volcanic glass occurrences in Washington: *State of Wash. Div. of Mines and Geol., Rept. of Investigations*, **17,** 1–77.

HURLBUT, C. (1936), *X*-ray determination of the silica minerals in sub-microscopic intergrowths: *Am. Mineral.*, **21,** 727–730.

IDDINGS, J. P. (1885), Obsidian Cliff, Yellowstone National Park: *U. S. Geol. Surv., 7th Annual Rept.*, 249–295.

ROSS, C. S. (1948), Optical properties of glass from Alamogordo, New Mexico: *Am. Mineral.*, **33,** 5 and 6, 360–363.

SMITH, G. O., AND CALKINS, F. C. (1904), A geological reconnaissance across the Cascade Range: *U. S. Geol. Surv., Bull.* **235,** 1–103.

TERZAGHI, RUTH D. (1948), Potash rich rocks of the Esterel, France: *Am. Mineral.*, **33,** 1 and 2, 18–30.

WILLIAMS, HOWEL (1931), The history and character of volcanic domes: *Univ. of Calif. Pub. in Geol. Sci.*, **21,** 51–146.

WASHINGTON, H. S. (1917), Chemical analyses of igneous rocks: *U. S. Geol. Surv., Prof. Paper* **No. 99,** 1–1201.

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