OBSERVATIONS ON PLAGIOCLASE AVENTURINES FROM SOUTHERN NORWAY

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Introduction

It is with some pride that we admit that, even with the aid of modern experimental and diagnostic equipment, we cannot add anything new to the excellent treatise on aventurine feldspars given more than 45 years ago by the Norwegian State Geologist Olaf Andersen (1915). The information given in the present paper mainly serve to prove the correctness of the suggestions made by Andersen, which he had no possibility to prove himself simply because the standard of diagnostic equipment was not sufficient for this purpose at that time.

Aventurine is no mineral name—it is a name of a yellowish to reddish schiller in minerals, it has been found in quartz, plagioclase, alkali feldspar, cordierite, cancrinite and carnallite. The aventurine effect in quartz and cordierite is mainly due to small flaky inclusions of mica, in feldspars, cancrinite and carnallite it is due to inclusions of hematite.

In plagioclase aventurines the hematite lamelli, being mostly less than 0.2 mm. across, may be oriented in a great many directions, but they generally occur parallel to (112), $(1\bar{1}2)$, (150) and $(1\bar{5}0)$. They have often hexagonal outlines, but eight- and ten-sided as well as irregularly shaped individuals also frequently occur. Under the binocular it becomes evident that the red color of the aventurine feldspars is due to the color of the hematite inclusions, and whereas the interference colors by the unaided eye seem to be mostly yellowish and reddish, all spectral colors may be seen under magnification.

The hematite lamelli disappear when the aventurine feldspar is heated above 1200 °C. It is not quite clear what causes the disappearance, but melting phenomena have been suggested (Andersen (1915)). In the light of results brought about during the later years it seems quite possible that hematite may be dissolved in a silicate melt without causing any coloring if reducing agents are absent. When decolorized aventurine feldspars are annealed at around 1000 °C the flakes reappear in their original places.

The studied plagioclases consist of a red core with a more or less pronounced aventurine effect and a milky white to clear and colorless mantle. Albite twins regularly occur, in some specimens they seem to vanish in the center of the core. Pericline twins are sometimes found together with albite twins, pericline twins alone have not been recorded.

Results and discussion

The differences in chemical composition as well as in structural state (as determined with the plagioclase thermometer) between the red core and the white mantle have been studied in some detail.

We confirm the findings of Diviljan (1961) that the iron content of plagioclase aventurines and their white mantle is low and seems not to exceed 2000 ppm by any appreciable amount. There seems to be no connection between the iron content and the aventurine effect, the white mantles sometimes contain more iron than do the red aventurine cores. The composition of the feldspar appears to be uniform throughout the crystal individuals, although there seems to be a general trend that the An content is somewhat higher in the core than in the mantle. Certain differences in the chemical composition from one crystal to another within the same pegmatite are common, thus the An content of the white mantle of one crystal may be the same as that of the red core of the neighbouring crystal. Sometimes there is a marked difference in the K_2O content: the white mantle being richer in the K-feldspar molecule than is the core, as evident from the analysis of the Bjordammen I sample of Table 1. This is, however, neither a rule nor an exception, and its relevancy to the aventurine effect is doubtful.

The results of the X-ray powder investigation seem to be somewhat more informative: From a series of twenty samples taken across the

Table 1. Analysis of three aventurine plagioclases; Na_2O is determined by flame photometry, K_2O, CaO and Fe_2O_3 by X-ray fluorescence.

	Na_2O	K_2O	CaO	Fe_2O_3	Ab	K-fsp.	An
Bjordammen I	%	%	%	%	%	%	%
red core	9.21	0.34	3.84	0.12	77.9	0.2	21.8
white border	8.46	1.02	4.88	0.17	71.6	0.6	27.7
Bjordammen II							
red core	7.81	0.77	5.88	0.10_3	66.1	0.5	33.4
white border	7.90	0.85	5.77	0.10_5	66.8	0.5	32.7
Havredal							
red core	10.29	1.03	2.17	0.05_1	87.1	0.6	12.3
white border	10.39	1.03	2.02	0.04_2	87.9	0.6	11.5

border between the aventurine cores and the white mantles it became evident that there is a marked difference in the structural state between the red core and the white mantle. In half of the samples the white mantle has a definite and higher structural state than has the core; in the rest of the samples Randomly Disordered structures, indicating indefinite but mostly higher structural states, were found in the white mantle. All the investigated red cores represent lowest thermal state according to the plagioclase thermometer (page 383).

Andersen (1915) writes (p. 380):

> The aventurine feldspars have been formed by unmixing of an originally homogeneous solid solution of the feldspar and hematite (or ferric compound) in such a manner that thin lamellæ have separated along structural planes (translation planes) of the feldspar.

We can only add, that the results of our X-ray investigation favour this interpretation, as long as iron is more likely to be accepted in small amounts in the high-thermal state than in the low-thermal state of the plagioclase lattice. (See e.g. Coombs (1954)).

From geological observations in the area where the aventurine plagioclase of South Norway is found it is evident that high temperature and moderate water activity existed for a very long period. We believe that the plagioclases grew in a metastable high thermal state as homogeneous crystals where ferric ions were accepted in the tetrahedral positions to an amount of 1 per cent or less of the total Al. During the time of growth a slight ordering took place, and upon gradually approaching the low thermal state iron was expelled from the tetrahedral positions in the lattice. The repulsion of iron, however, neccessitates a slight migration of aluminium towards the center of the crystal and, therefore, depend upon the time available for the aluminium ions to migrate through the lattice as well as upon the temperature, water activity and tectonic conditions. The fact that the mantle of the aventurine is white is probably due to the fact that it is younger than the core and, therefore, has not had sufficient time to reach the lowest structural state.

Is is certainly true that exceptionally long times must have been involved in these migration processes—such long time at favourable temperature—pressure—fluid-activity conditions seem to have been available in the South Norwegian area where aventurine oligoclase bearing pegmatites are found.

We are aware that our interpretations concerning the formation of aventurine oligoclases may be subject to discussion, but the facts remain that the chemical composition is almost the same in the aventurine core and in the white mantle, and that hematite is exsolved as thin lamelli in the aventurine core which represents a lower thermal state than does the hematite free white mantle.

Our viewpoints represent a model which is based upon two assumptions:

a) that the plagioclases grew in a high thermal state

b) that ferric ions are accepted more readily in tetrahedral positions in the high structural state than in the low one, and that if aluminium ions in the required quantity is available, iron may be exsolved from the low thermal state plagioclase.

We want to emphasize that we have observed indications for interesting cation migration processes in the aventurine plagioclases. Referring to these observations one of us (O.H.J.C.) postulated the existence of a Contamination Expelling Principle during the discussions of the Advanced Study Institute of Feldspar. This principle seems to be of importance in petrology and has been active in the South Norwegian Precambrian at a certain stage of the petrogenesis (Thorough Metamorphism of H.N.). We believe, however, that the influence of cation diffusion processes have but a secondary influence upon the development of aventurine plagioclases, implying retarding or accelerating effects upon the ordering process.

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