

**DYNAMIC CRYSTALLIZATION CHARACTERISTICS OF ADOR;** Gary Lofgren, SN-2 NASA Johnson Space Center, Houston, TX 77058; and A. B. Lanier, LESC, 1830 NASA Rd. 1, Houston, TX 77258.

The discovery of Angrites in the Antarctic collection (1-3) has renewed interest in Angra Dos Reis (ADOR). Prinz et al. (4) originally proposed a cumulate origin, but more recently Treiman (1) has suggested that ADOR is a porphyry with skeletal phenocrysts. If ADOR is a porphyry then some significant portion of its cooling history must have been low pressure with cooling rates which can be duplicated in the laboratory. Dynamic crystallization experiments were conducted on synthetic ADOR (Table 1) to determine its crystallization characteristics.

The bulk composition of ADOR is very close to that of its principal phase, fassaite. Consequently the material crystallizes very easily. The liquidus temperature is 1263°C. Fassaite is the only phase to crystallize over a broad temperature interval. In a series of experiments with increasing melt temperature from just below the liquidus temperature to well above (1260-1325°C), the texture does not vary significantly. The fassaite varies from equant to elongate tabular to increasingly skeletal and larger as the melt temperature increases. In charges melted at 1325°C, the fassaite is large, up to 3 mm in diameter, and skeletal. The size of the experimental charge, 4 mm, probably limits the crystal size. At melt a temperature of 1350°C, there is an abrupt change to a highly (tree like) dendritic crystal form. In experiments with melt temperatures below 1260°C, significant numbers of crystals grow and settle to the bottom of the charge. Upon cooling, a large disparity in crystal size develops between the early crystals and those that grew upon cooling. The overall grain size of these experiments is smaller than experiments in which the initial melting is complete.

A series of experiments were conducted with cooling rates in the range 2 to 2000°C/hr from a melt temperature of 1265°C to explore the effect of cooling rate on texture and crystal shape. At 2 & 5°C/hr, the crystals are equant to elongate tabular (Fig. 1). At 50 & 100°C/hr the crystals are markedly more elongate skeletal and at 250°C/hr there is a transition to the tree like dendritic form similar to that observed in 5°C/hr cooling runs melted at 1350°C. At 1000 and 2000°C/hr, the fassaite dendrites are tree like with increasingly finer branches. A fine equigranular material first appears at the slower cooling rate and is dominant at the higher one. The transitions from dendritic to spherulitic to the equigranular material are sharp.

In all the experiments, fassaite is the major phase to crystallize comprising up to 95 volume % of the charge. The fassaite is homogeneous throughout most of the crystal with a thin zoned rim. The matrix phases include kirschsteinite, titanian magnetite, an Al rich spinel, a pyroxferroite like phase (as yet to be identified), metallic Fe, and glass (Table 1). In the 5°C/hr experiment quenched at 1100°C, the matrix has not yet begun to crystallize and the fassaite is well over 60% by volume. In an identical experiment which was held at 1100°C for 3 days, a couple of spinel crystals are present thus the bulk of the matrix crystallizes between 1100 and 1000.

A series of experiments were conducted to look at variations in oxygen fugacity. The intrinsic oxygen fugacity of ADOR is approximately 1.2 log units above the IW buffer curve (5). Experiments were conducted at the IW buffer, 0.6, and 1.2 log units above IW, and at QFM. There are changes in the matrix mineralogy, the compositions of the minerals, and the liquidus temperature which increases slightly at QFM. The compositions of the principal phases are given in Table 1 and are representative of the intrinsic oxygen fugacity. The Fassaite is zoned from the core to the rim compositions shown in Table 1. Most of the fassaite is nearly homogeneous with the bulk of the zoning in the outer 10-100 microns of the typically several mm long crystals. The Kirschsteinite is interstitial to the fassaite and occurs in the greatest amounts and largest crystals at the intrinsic oxygen fugacity. The crystals are not zoned, but contain patches of CaO rich olivine. The pyroxferroite like phase appears to react to spinel with increasing oxygen fugacity and is not

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present at QFM. It loses FeO and gains  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and MgO at the lower oxygen fugacity of the IW buffer. The spinels are rare at IW and increase in amount until they totally replace the pyroxferroite like phase at QFM. They gain  $\text{TiO}_2$ , and lose FeO at IW while the other minerals do not change compositions significantly at the lower or higher oxygen fugacities.

The crystallization characteristics of ADOR are consistent with a volcanic or hypabyssal origin. Large skeletal phenocrysts similar to those proposed by Treiman (1) will grow readily. If the system is quenched after the growth of the appropriate number of phenocrysts have grown, textures, which could recrystallize to the observed texture in ADOR, are observed at the most rapid cooling rates. There are still problems. Olivine does not crystallize, Kirsch is more plentiful than in ADOR. It is possible that the composition used is not correct. If the composition can be shifted within the range of possible ADOR compositions to stabilize olivine that problem could be alleviated.

REFERENCES: (1) Treiman A.H. (1989) Proc. Lunar Planet. Conf. 19th, 443-450. (2) McKay G., Le L. and Wagstaff J. (1989) Lunar and Planetary Science XX, 675-676. (3) Mittlefehldt D.W., Lindstrom M.M. and Lindstrom D.J. (1989) Lunar and Planetary Science XX, 701-702. (4) Prinz et al. (1977) Earth Planet. Sci. Lett., 317-330. (5) Brett R., Huebner S. and Sato M. (1977) Earth Planet. Sci. Lett., 363-368.



Figure 1. Photomicrograph of experimental charge cooled at  $50^\circ\text{C/hr}$ . Large equant to elongate fassaite comprised most of the charge. Interstitial kirschsteinite, titanian magnetite, spinel, a pyroxferroite like mineral and glass are present. The charge is approximately 4mm in diameter

Table 1. Chemical compositions of the starting material, ADOR, and the major phases grown in the experiments. The composition of ADOR was obtained from D. W. Mittlefehldt, personal communication.

OXIDE	ADOR START	FASSAITE CORE	FASSAITE RIM	KIRSCH	KIRSCH PATCHES	TIMAG	SPINEL	PYFERRO LIKE
$\text{SiO}_2$	44.29	48.92	41.47	31.13	30.48	0.22	0.15	24.33
$\text{TiO}_2$	1.97	1.39	1.46	0.09	0.09	10.80	2.71	4.00
$\text{Al}_2\text{O}_3$	9.25	5.72	11.11	0.11	0.07	15.66	44.21	16.80
$\text{Fe}_2\text{O}_3$						30.39		
FeO	10.20	3.70	18.71	43.45	54.81	41.42	48.37	40.94
MnO	0.09	0.04	0.16	0.62	0.67	0.25	0.19	0.17
MgO	10.52	14.56	3.47	3.73	6.22	1.64	4.45	0.44
CaO	23.00	24.17	23.27	20.13	7.39	0.08	0.14	12.84
$\text{Na}_2\text{O}$	0.03	0.00	0.03	0.02	0.01	0.02	0.00	0.06
$\text{Cr}_2\text{O}_3$	0.21	0.37	0.02	0.01	0.01	0.01	0.01	0.01