EXPERIMENTAL STUDY OF SILICATE-SULFIDE-Fe METAL EQUILIBRIA IN BASALTS.

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INTRODUCTION. The potential significance of an Fe-rich sulfide phase in magma petrogenesis and in planetary differentiation processes is recognized but not well understood (1) partly because of the lack of experimental data on silicate-sulfide systems. For example, some basalts on the earth are very close to saturation with an Fe-rich sulfide when extruded (3) but the affect of the various intensive parameters on the solubility of S in basaltic melts is not well known. As a result, it is not clear whether FeS is a residual phase in the source regions of these magmas, or whether FeS fractionation occurred as the magmas moved to the surface. There is also the unsolved problem regarding the presence of light elements in the cores of terrestrial type planets. Sulfur has been proposed as one of the elements likely to be present in the earth, the Moon and in Mars (3,4,5) but the basic sulfide-silicate element partitioning data required to test this hypothesis is lacking. Two sets of experiments are described here which attempt to answer some of the above questions.

BASALT-C-O-Fe-S EXPERIMENTS. The initial set-up of experiments in this system (Table 1) consists of a mixture of basalt (glass or partly crystalline) + FeS + minor $FeCO_3$ surrounding a thin strip of Fe-foil, all in a spec-pure graphite container sealed in Pt. These samples were run in an internally heated pressure vessel in the range 1 atm to 5 kb and 1050° to 1250°C. Most experiments were above the basalt liquidus. The resulting assemblage in each case was a silicate melt mass in the graphite nearly surrounded by lens-shaped FeS-rich masses (Fig. 1). The FeS commonly contained one or more spherical blebs of Fe-metal (Fig. 2). Very small ($<10\mu$) spherules of FeS and Fe also occur scattered through the silicate. The morphology of the phases produced in these experiments clearly indicates that the Fe-metal as well as the sulfide and silicate were molten above 1150°C. This is well below the two-liquid field in the Fe-S-O system (6), but the liquid state of Fe is consistent with Fe-C phase relations (7) which indicate an Fe-rich eutectic containing 4.2 wt% C at 1153°C. We have confirmed this observation with our own 1 atm experiments.

The basalt-C-O-Fe-S experiments do not significantly change the conclusions reached in recent experimental studies (8,9) as regards S solubility in basalts. The solubility is (a) strongly a function of FeO in the melt and (b) it remains essentially constant with increasing pressure in the system. The temperature effect cannot be evaluated from these experiments, but Danckwerth (9) has found it to be very complex. Possibly a more important outcome of these experiments is the observation that the M.P. of Fe-metal coexisting with graphite and an FeS rich phase is lowered to less than 1150°C (from 1320°C) because the metal contains 4 wt% C (along with 1% or less of S, P and Si). It would appear that at appropriately low fo_2's, and at least at low pressures such as those in the Moon and some meteorite parent bodies, significant amounts of C and some Si and P as well as S and O (1) could have been removed with separation of a metal phase during early melting events.

BASALT-H-O-Fe-S EXPERIMENTS. In an attempt to evaluate the role of H on sulfur solubility in basic magmas, experiments have been done on the same two basalts studied in the H-free system and on a natural dacite (Table 1). These experiments were also done with excess Fe and FeS, but in sealed Pt capsules previously saturated with Fe. The f_{H_2} was controlled externally by a C-CH_4 assemblage. The phases produced in addition to silicates were two Fe-Pt alloys with compositions close to those defined by the solvus in this system (7), an Fe-rich sulfide and a vapor.

The importance of these experiments (Table 1) is that they (a) demonstrate hydrothermal silicate melt-sulfide experiments can be done (b) indicate that the presence of H produces about a 50% increase in the amount of sulfur in a basaltic melt relative that in similar, but dry, melt systems, (c) show that amphibole can be stable up to 1070°C at 2 kb, which is 200° above the breakdown temperature when $P_{H2O} = 0.6\ P_F$.

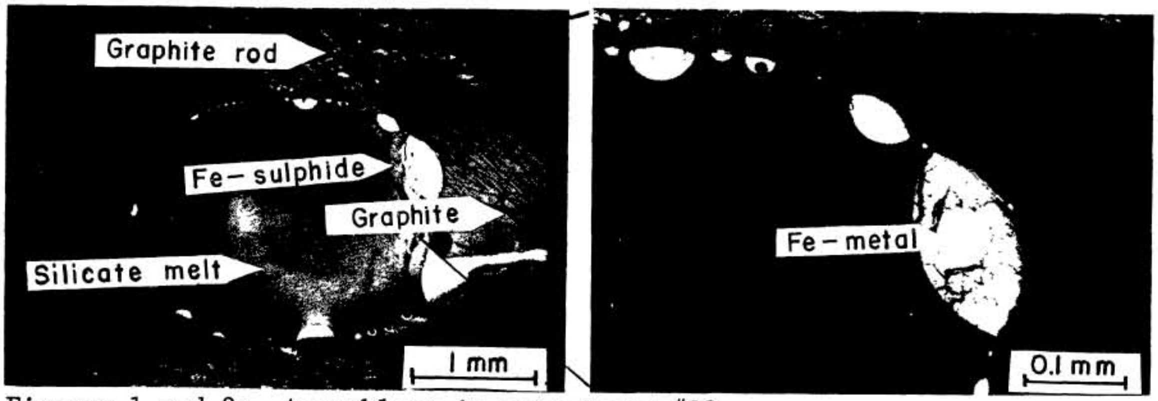
References: (1) Brett, R. (1977) Abst. Experimental Trace Element Geochem. conf., Sedona, AZ. (2) Mathez, E. (1976) J. Geophys. Res., 81, 4269-4276. (3) Mason, B. (1966) Nature, 211, 616-618. (4) Johnson, D.H. and Toksoz, M.N. (1977) Incarus, 32, 73-84. (5) Murthy, V.R. and Hall, H.T. (1970) Phys. Earth Planet. Int., 2, 276-282. (6) Hilty, D.C. and Crafts, W. (1952) Jour. of Metals, 1307-1312. (7) Hansen, M. and Anderko, K. (1958) Const. of Binary alloys, 2nd Ed., McGraw Hill, NY. (8) Wendlandt, R.F. (1981) GSA Abst. with Prog., 578. (9) Danckwerth, P. (MS) Unpub. MS in Ph.D. thesis, Brown University.

TABLE 1: SILICATE-SULFIDE-Fe-METAL EXPERIMENTS

#	Starting[1] Material	T °C	P Kb	Time hrs.	Products[2] - Composition in wt% Silicate Melt FeO	Silicate Melt S	Fe Metal
System C-O-S							
38	1	1150	4.5	4	14.0	.15	C = 4. S 1.0 P = 0.6 Si= 0.3
41	1	1150	0.2	4	14.4	.18	
71	1	1250	3.5	3	7.3	.08	n.a.
75	1	1050	3.5	7	26.5	.32	n.a.
72	2	1250	2.5	3	9.2	.10	n.a.
System H-O-S							
46B	1	1080	2.0	3	14.3	.23	Olv., Fe, FeS, G
69B	3	950	2.0	5	14.6	.05	Pyx., Plag., G
45	1	1070	2.0	3	12.	.05	Olv., Amph., Fe, FeS, G

[1] Starting Materials are (1) An evolved basalt, 1080°C dry liquidus, FeO= 12.0, SiO_2= 54. (2) A natural primitive tholeiite (Do8) and (3) A Mt. St. Helens dacite.

[2] Products also included an FeS-rich melt which separated into FeS and Fe metal during the quench. The scale of separation makes analysis by microprobe extremely difficult.



Figures 1 and 2: Assemblage in experiment #38.