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Tracing pre-eruptive magma degassing using ($^{210}Pb/^{226}Ra$) disequilibria in the volcanic deposits of the 1980–1986 eruption of Mount St. Helens

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Abstract

Disequilibria between ^{210}Pb and ^{226}Ra can be used to trace magma degassing, because the intermediate nuclides, particularly ^{222}Rn, are volatile. Products of the 1980–1986 eruptions of Mount St. Helens have been analysed for ($^{210}Pb/^{226}Ra$). Both excesses and deficits of ^{210}Pb are encountered suggesting rapid gas transfer. The time scale of diffuse, non-eruptive gas escape prior to 1980 as documented by ^{210}Pb deficits is on the order of a decade using the model developed by Gauthier and Condomines (Earth Planet. Sci. Lett. 172 (1999) 111–126) for a non-renewed magma chamber and efficient Rn removal. The time required to build-up ^{210}Pb excess is much shorter (months) as can be observed from steady increases of ($^{210}Pb/^{226}Ra$) with time during 1980–1982. The formation of ^{210}Pb excess requires both rapid gas transport through the magma and periodic blocking of gas escape routes. Superposed on this time trend is the natural variability of ($^{210}Pb/^{226}Ra$) in a single eruption caused by tapping magma from various depths. The two time scales of gas transport, to create both ^{210}Pb deficits and ^{210}Pb excesses, cannot be reconciled in a single event. Rather ^{210}Pb deficits are associated with pre-eruptive diffuse degassing, while ^{210}Pb excesses document the more vigorous degassing associated with eruption and recharge of the system.

Keywords: Pb-210; Ra-226; Mount St. Helens; degassing; time scales

1. Introduction

Volcanic eruptions are driven largely by exsolution of volatiles from subsurface magma [e.g. 1,2]. The dynamics of this process are intrinsically linked to eruption style. If volatiles can escape from the magma, the buoyancy of the gas–magma mixture diminishes and with that the likelihood for an explosive eruption. On the other hand, gas bubbles can be trapped in the magma resulting in pressure build-up until a critical threshold is reached and the magma erupts explosively. Knowledge of the timescales over which magmas lose their volatiles, and changes occur in degassing behaviour, is thus highly desirable.

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Table 1
Data

Sample number[a]	Sample type	Eruption date	(^{226}Ra) (Bq/kg)	(^{210}Pb)$_0$ (Bq/kg)[b]	(^{210}Pb/^{226}Ra)$_0$	2 stdev	Average density (g/cm^3)[c]	stdev
SH10	Dense juvenile clast from phreatic explosion	13/04/1980	16.15	19.41	1.20	0.03	1.19	0.43
KC518PFA	Microlite-free pumice from pyroclastic flow	18/05/1980	14.26	12.16	0.85	0.03	0.59	0.02
KC518PFB	Microlite-free pumice from pyroclastic flow	18/05/1980	14.11	12.09	0.86	0.03	0.50	0.03
SH80M light	Mixed pumice, light part	18/05/1980	13.44	12.02	0.89	0.03		
SH80M dense	Mixed pumice, dense, dark part	18/05/1980	14.35	16.36	1.14	0.03		
SHKB24	Dense cryptodome fragment in blast deposit	18/05/1980	14.14	15.65	1.11	0.03	1.69	0.11
C-C85-310	Grey pumice from the early stages of the eruption	18/05/1980	13.57	13.92	1.03	0.03		
C-T8G	Pumice from the Late Plinian tephra layer	18/05/1980	14.55	10.61	0.73	0.03		
C-T8W	Pumice from the Late Plinian tephra layer	18/05/1980	14.16	18.26	1.29	0.03		
SHKB45	Pumice from top of upper pyroclastic flow deposits	18/05/1980	13.52	12.12	0.90	0.03	0.68	0.04
SHKB29	Pumice from earliest pyroclastic flows	18/05/1980	13.95	12.90	0.92	0.02	0.56	0.04
SHKB26	Airfall pumice	18/05/1980	13.54	17.38	1.28	0.03	0.78	0.00
SHKB30B	Pumice from bottom of the lower pyroclastic flow deposits	18/05/1980	11.32	9.21	0.81	0.03	0.76	0.05
SHKB30T	Pumice from top of the lower pyroclastic flow deposits	18/05/1980	12.62	10.96	0.87	0.03	0.74	0.13
SHKB38A	Pumice from top of the middle pyroclastic flow deposits	18/05/1980	12.13	11.38	0.94	0.03	0.75	0.01
SHKB38B	Pumice from a pumice lens within the middle pyroclastic flow deposits	18/05/1980	11.93	11.36	0.95	0.03	0.60	0.06
USNM115464-11	Blast deposit	18/05/1980	13.41	11.16	0.83	0.04	0.78	0.09
SHKB25	Slightly vesicular cryptodome fragment from blast deposit	18/05/1980	14.22	15.79	1.11	0.04	1.07	0.03
USNM115379-31	Airfall pumice	25/05/1980	14.45	12.03	0.83	0.02	0.58	0.07
CVO-May25P	Airfall pumice	25/05/1980	13.95	11.54	0.83	0.03	1.10	0.04
KC612PF	Pumice from pyroclastic flow	12/06/1980	13.34	12.47	0.93	0.03	1.21	0.01
USNM115379-40	Dome fragment	12/06/1980	12.34	13.30	1.08	0.03	1.56	0.03
KC722LB	Pumice from pyroclastic flow	22/07/1980	14.77	17.80	1.21	0.04		
KC722U	Pumice from pyroclastic flow	22/07/1980	14.92	19.18	1.29	0.03	0.62	0.05
SHKB34	Dense pumice in levee of 7/8/1980 pyroclastic flow, possibly July plug	22/07/1980	14.65	16.29	1.11	0.03	0.73	0.04
KC807B	Pumice from pyroclastic flow	07/08/1980	14.14	19.96	1.41	0.04	0.49	0.03
KCJ-1	Airfall pumice	07/08/1980	15.36	21.40	1.39	0.05	0.37	0.01
SHKB23	Denser pumice in the levee of 10/80 pyroclastic flow	07/08/1980	13.33	12.33	0.92	0.03	1.05	0.06
USNM115418-42	Pumice	16/10/1980	13.43	11.17	0.83	0.04	0.67	0.07
USNM115418-60-2	Dome fragment	16/10/1980	12.74	12.29	0.96	0.03	0.66	0.05
USNM115418-61	Dome fragment	16/10/1980	14.42	20.82	1.44	0.03	1.06	0.17
USNM115427-4	Dome fragment	27/12/1980	13.01	14.03	1.08	0.03	1.11	0.03
USNM115427-1	Pumice	27/12/1980	12.67	11.07	0.87	0.03	0.47	0.05
USNM115434	Dome fragment	05/02/1981	13.56	12.97	0.96	0.04	1.20	0.12
USNM115439	Dome fragment	10/04/1981	13.18	16.33	1.24	0.03	0.79	0.12
USNM115465	Dome fragment	18/06/1981	12.72	11.09	0.87	0.03	0.65	0.03
KC681	Dome fragment	18/06/1981	15.02	20.90	1.39	0.03	1.25	0.00
USNM115525	Dome fragment	06/09/1981	12.46	12.12	0.97	0.04	0.58	0.00
USNM115543-109	Dome fragment	30/10/1981	12.39	11.28	0.91	0.03	1.21	0.04
USNM115773-3	Pumice	19/03/1982	13.12	14.82	1.13	0.05	0.33	0.03
USNM115773-18	Dome fragment	19/03/1982	12.36	11.66	0.94	0.04	1.49	0.06
SH127	Dome fragment	14/05/1982	16.25	17.07	1.05	0.03	0.98	0.04