An experimental investigation of the Panzhihua igneous complex, SW China - Addressing the genesis of Fe-Ti-V oxide ore deposits

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Introduction

The Late Permian Panzhihua layered gabbroic intrusion of SW China hosts one of the largest magmatic Fe-Ti-V oxide deposits within the Emeishan large igneous province and is coeval with peralkaline granitic rocks. The largest oxide ore body is found at the base of the intrusion which is unlike other layered intrusions where the Fe-Ti oxide deposits are located in the uppermost portions. There have been numerous studies on this intrusion which focused on the mineral chemistry, geology, geochemistry and geochronology. Consequently there are three main hypotheses regarding the formation of oxide ore deposits and host rocks of Panzhihua complex. 1) silicate liquid immiscibility, 2) fractional crystallization of a basaltic parental magma which produces the gabbro, ore and neighboring peralkaline granite and 3) the gabbro and ore are derived from an ultramafic parent and is mutually exclusive from the granite.

This study attempts to model the genesis of the Panzhihua layered intrusion, including the formation of the ore deposit, using a starting composition equal to high-Ti Emeishan basalt at atmospheric pressure. The experimental results show that the first mineral to crystallize is iron oxide, followed by the crystallization of clinopyroxene ($Wo_{39-52}En_{39-52}Fs_{8-16}$), orthopyroxene and plagioclase ($An_{67-41}Ab_{29-47}Or_{2-17}$). The composition of residual liquid is silicic with the enrichment of SiO_2, Al_2O_3, Na_2O, K_2O and depletion of TiO_2, FeO, MgO and CaO.

Geological setting

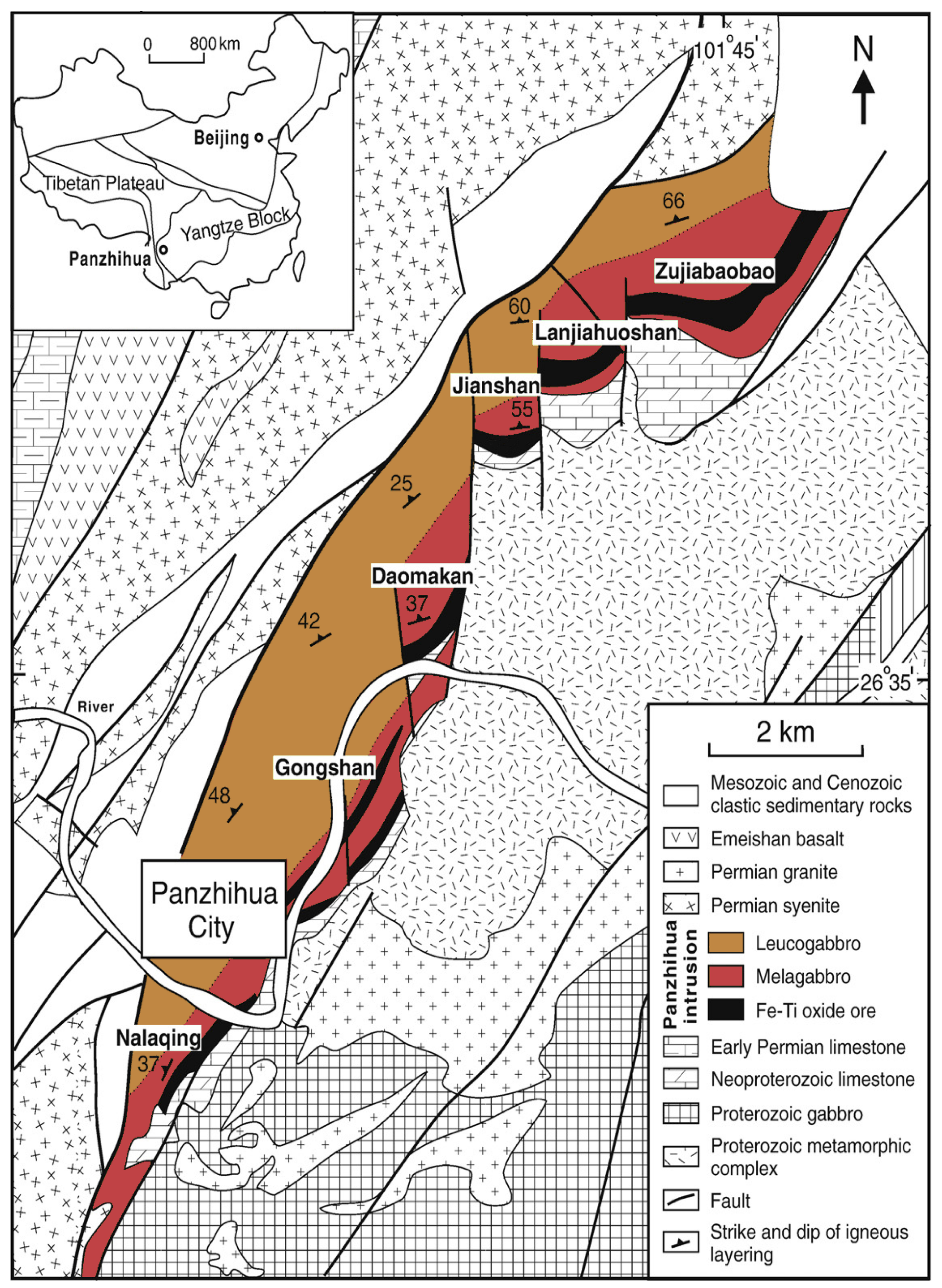


Fig 1. The Emeishan Large Igneous Province (ELIP) located in the SW China includes flood basalt and associated mafic-ultramafic intrusions. The Panzhihua intrusion is a gabbroic layer intrusion that hosts Fe-Ti oxide ores in the central western ELIP. It is a sill-like body that dips 50-60°NW, extends NE-SW for about 19 km, and is composed of cumulate gabbro and oxide deposits (modifed from Pang et al., 2013)

Table 1. Estimates for the parental magma compositions of the Panzhihua intrusion

Intrusion	SiO_2 (wt%)	TiO_2	Al_2O_3	$Fe_2O_3^t$	FeO^t	FeO	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total	Mg#
Panzhihua[1]	48.03	2.87	11.26	12.37				0.19	8.54	10.29	2.23	1.09	0.3	2.69	99.86	57.8
Panzhihua[2]	42.6	3.99	15.8		15.6			_	5.99	11.9	2.45	0.31	0.69		99.2	46
Panzhihua[3]	49.18	2.94	11.53	12.67				0.19	8.74	10.54	2.28	1.12	0.31	0.5	100	57.8
Panzhihua[4]	45.83	4.85	15.62			11.36	2.23	0.23	7.18	7.52	3.26	1.41	0.51		100.01	53

[1] Starting composition of this study (Sample GS03-003), [2] Zhou et al. (2005), [3] Shellnutt et al. (2011b), [4] Pang et al. (2008b)

Results

Table 2. Anhydrous melting experiment shows crystallization sequence of high-Ti Emeishan basalt. Cpx: clinopyroxene; Gl: glass; Opx: orthopyroxene; Plag: plagioclase

Samples	Temperature (°C)	Duration (hr : min)	Mineral phases
Pz-001	1312	6:00	Gl
Pz-003	1303	6:00	Gl
Pz-013	1274	7:30	Gl+ Fe-Cr oxide
Pz-007	1252	19:00	Gl+ Fe-Ti oxide
Pz-004	1201	7:00	Gl+ Fe-Ti oxide
Pz-012	1194	15:00	Gl+Fe-Ti oxide
Pz-008	1188	23:45	Gl+Fe-Ti oxide+Cpx
Pz-006	1171	19:00	Gl+Fe-Ti oxide+Cpx
Pz-009	1162	25:25	Gl+ Fe-Ti oxide +Cpx+Opx+Plag
Pz-005	1151	9:00	Gl+ Fe-Ti oxide+Cpx
Pz-010	1122	23:00	Gl+ Fe-Ti oxide+Cpx
Pz-011	1114	25:15	Gl+ Fe-Ti oxide+Cpx+Plag
Pz-002	1102	65:25	Gl+ Fe-Ti oxide+Cpx+Plag

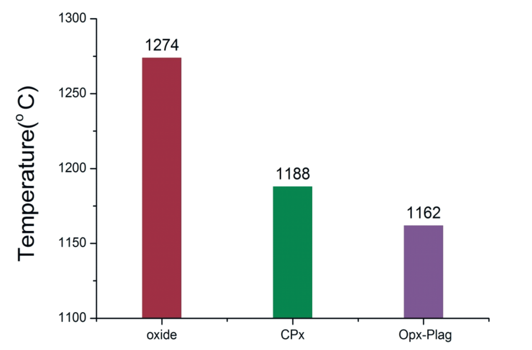
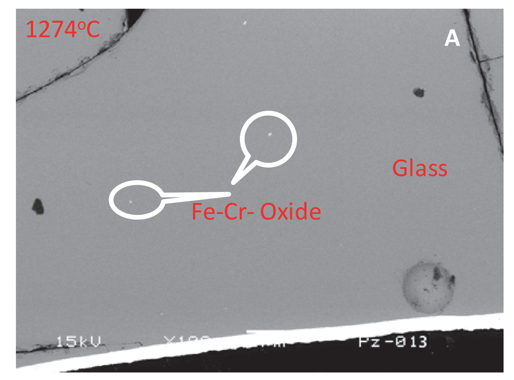


Fig 2. The crystallization sequence of basaltic magma constructed by experiment



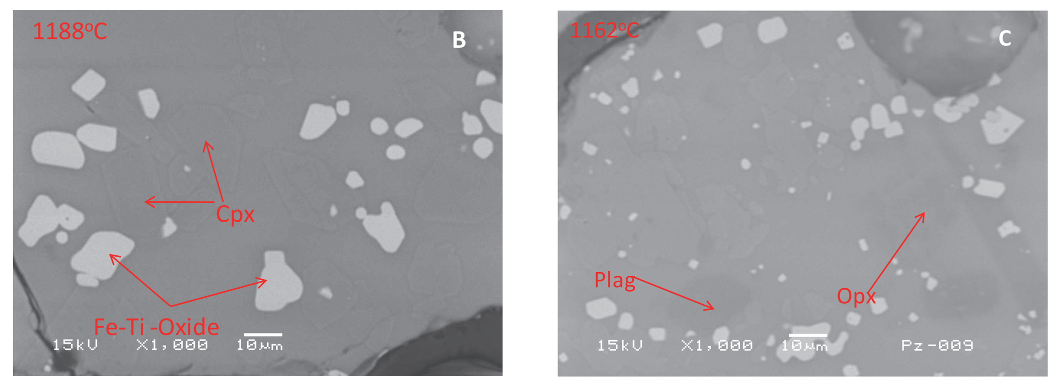


Fig 3. SEM images of mineral crystallization at different temperatures
A: Fe-Cr oxides start to crystallize at 1274°C. B: Cpx start to crystallize at 1188 °C.
C: Opx and Plag start to crystallize at 1162°C

Table 3. Major element composition of minerals and glass at different temperature (100%)

Minerals	Fe-Cr oxide	Fe – Ti oxide	Cpx	Opx	Plag	Glass	Glass	Glass	Glass	Glass	Glass	Glass
Sample	Pz013	Pz009	Pz002	Pz009	Pz002	Pz003	Pz013	Pz008	Pz009	Pz002	Pz002	Pz002
SiO_2 (wt %)	0.73	0.06	53.07	55.58	56.62	50.96	51.18	54.33	58.44	63.67	65.18	70.58
TiO_2	1.27	14.65	0.22	0.38	0.07	2.90	2.89	2.38	2.25	0.30	0.43	0.81
Al_2O_3	7.44	2.19	1.04	2.68	26.72	11.82	11.76	13.19	14.55	20.69	19.91	12.55
Cr_2O_3	10.49	0.38	0.05	0.06	0.00	0.02	0.02	0.01	0.01	0.00	0.00	0.00
FeO	62.00	75.74	7.56	4.20	0.56	11.36	11.31	7.73	5.54	1.68	1.78	2.85
MnO	0.68	0.18	0.15	0.25	0.00	0.13	0.16	0.14	0.14	0.00	0.03	0.10
MgO	16.99	6.57	15.04	34.54	0.07	8.91	8.89	8.02	5.87	0.71	0.74	3.90
CaO	0.36	0.20	22.62	2.25	9.96	10.45	10.41	10.22	8.11	6.00	5.56	2.64
Na_2O	0.05	0.01	0.25	0.06	5.32	2.35	2.31	2.70	3.11	4.26	3.59	2.22
K_2O	0.00	0.00	0.00	0.00	0.67	1.09	1.06	1.27	1.98	2.68	2.79	4.36

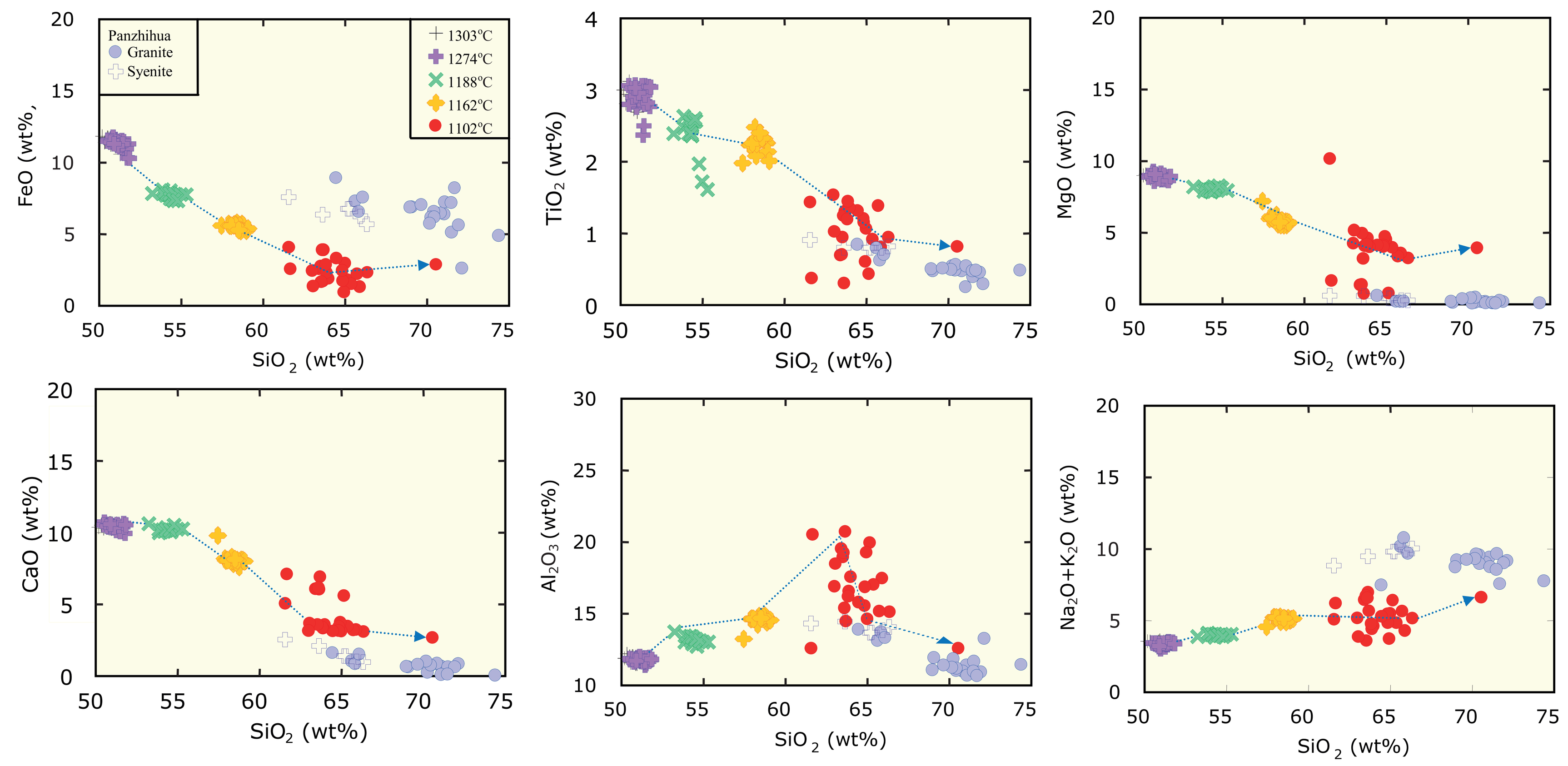


Fig 4. SiO_2 vs Al_2O_3, Na_2O+K_2O, MgO, CaO, FeO (as total iron) and TiO_2 for glass from experiment. The low temperature residual glass compositions are enriched in SiO_2, Al_2O_3, Na_2O, K_2O and depleted in TiO_2, FeO, MgO and CaO. Syenite and granite data from Shellnutt and Zhou (2007), Shellnutt and Jahn (2010).

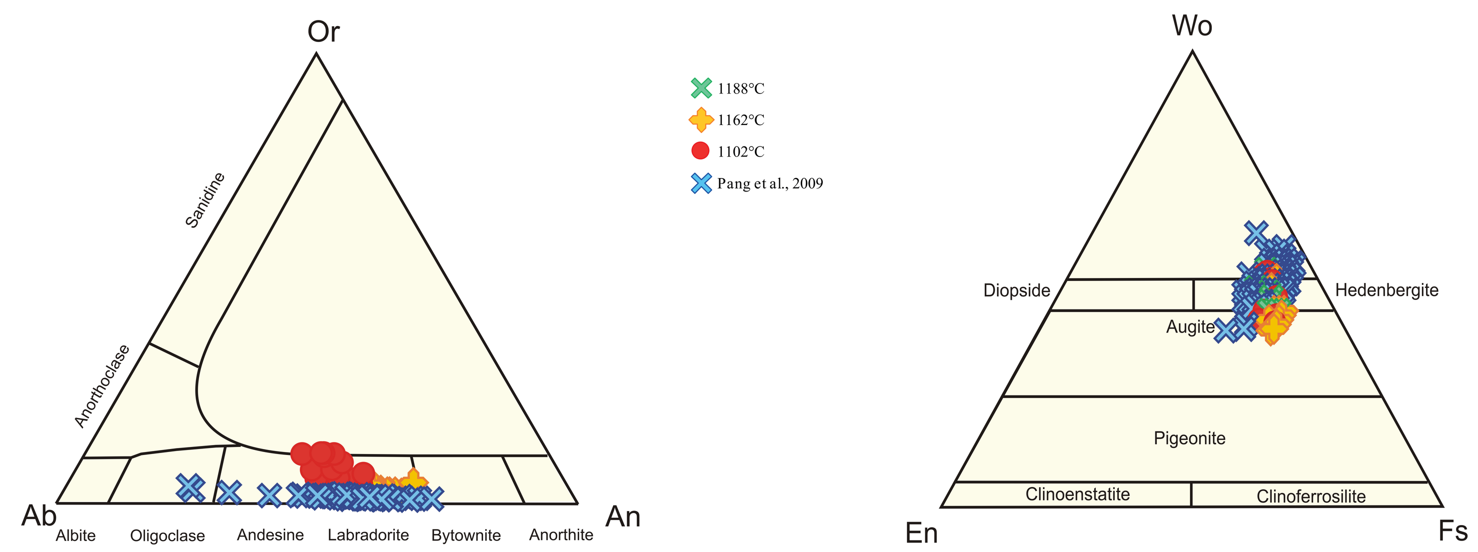


Fig 5. Composition of pyroxene and plagioclase in Panzhihua intrusion (Pang et al., 2009) and in this study. Clinopyroxene ($Wo_{39-52}En_{39-52}Fs_{8-16}$); Plagioclase ($An_{67-41}Ab_{29-47}Or_{2-17}$)

Conclusions

1. The results of the experiment indicate that the early crystallization sequence of the liquid is dominated by Fe-Ti oxide and can explain why the largest oxide ore deposits of the Panzhihua intrusion are found in the lowermost layers.

2. The residual glass compositions become more silicic, resemble spatially associated peralkaline silicic rocks found in close proximity to the layered gabbro and suggest that the two rock types form a coherent igneous complex.

3. The liquid-crystal evolution constructed from the experiment show that a parental magma similar to high-Ti Emeishan basalt can produce an early enrichment of oxide minerals and a silicic residual liquid.

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