Calorimetric Glass Transition Temperatures

&

Magmatic Processes

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GMPV2/IG20: Magmas, Melts, and Magma Mixing: from lab to nature.

SYNOPSIS

(1) Natural glasses record melt composition attending magmatic processes.

(2) Natural glasses form under diverse conditions. [silicic to mafic melts; fast to slow cooling]

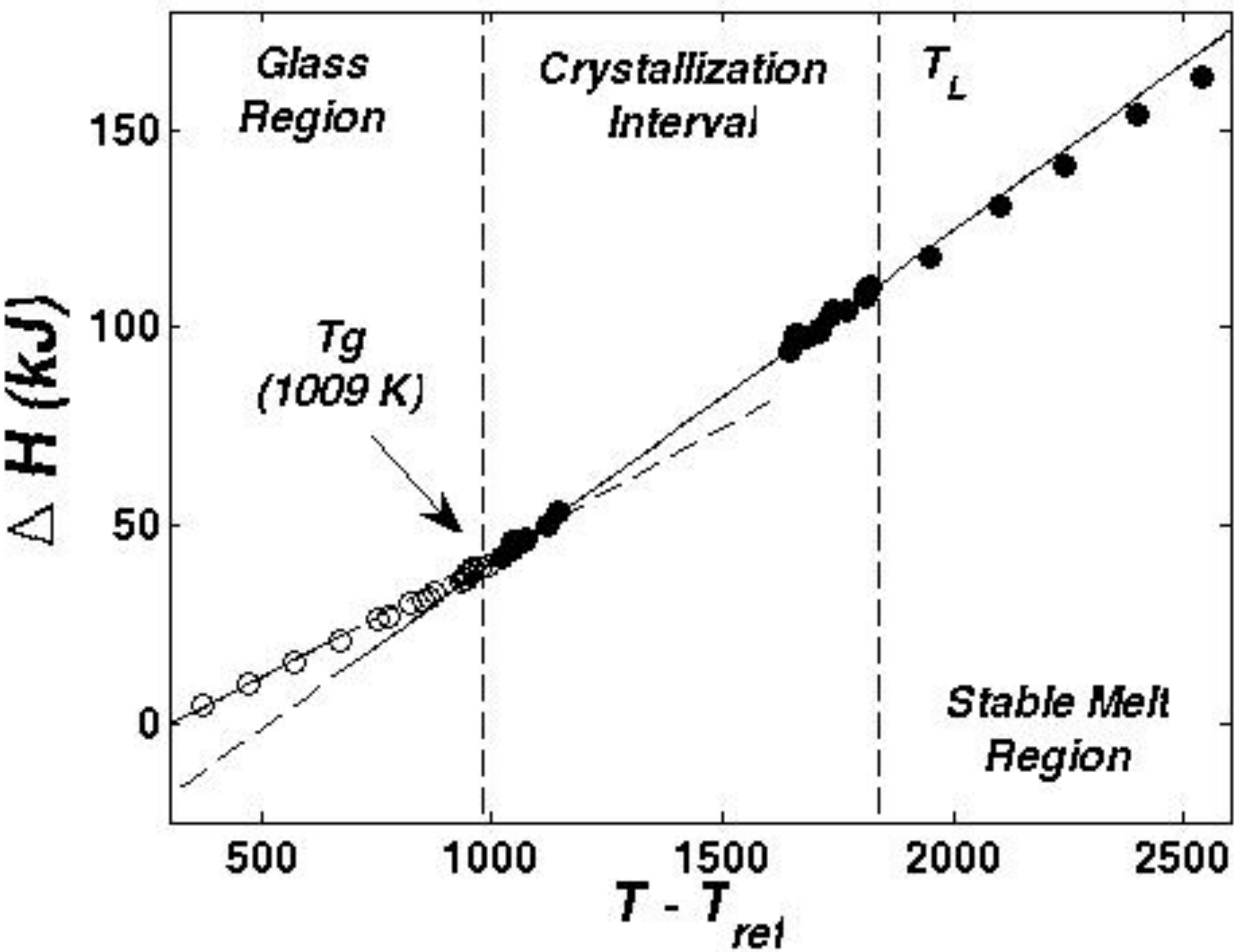
(3) Glass transition temperature (**Tg**) marks the transition from the liquid to the glassy state.

(4) Glass is the consequence of the liquid line of decent [**T-X**] intersecting the **Tg**

(5) EMPIRICAL MODEL PREDICTS CALORIMETRIC Tg AS A FUNCTION OF MELT COMPOSITION

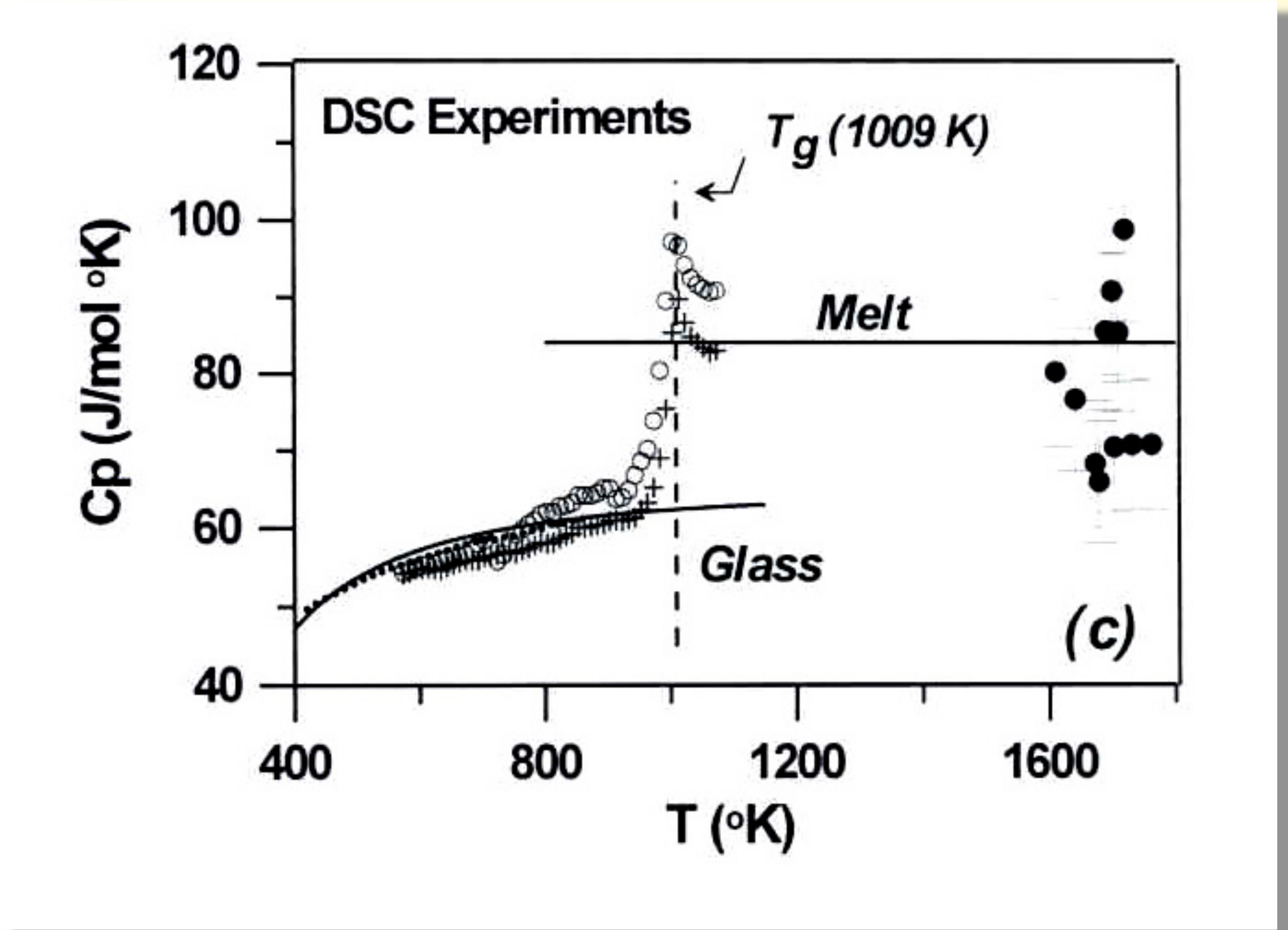
Adiabatic Drop Calorimetric Data

Melts (filled)
Glasses (open)



DSC vs. Model Functions:

Data: Stebbins et al. 1983; Knoche et al. 1992; Lange et al., 1991.



Empirical Model for predicting Tg in Natural Melts

Based on ADC datasets including:

> 500 experiments on 60 melt compositions

> 400 observations on 30 glass compositions

PLUS constraints from independent estimates of Tg

Provides T-dependent melt & glass heat contents curves

$$\Delta H_m = A \cdot T(K) + B$$

$$\Delta H_g = a \cdot T(K) + \frac{c}{T}(K) + d$$

Intersection of heat content curves defines Tg

Multicomponent Model for Calorimetric Tg

UNCONSTRAINED MODEL

$$X^2 = \sum_{i=1}^{n} \left\langle \frac{\Delta H_i^{obs} - h(T)_i}{\sigma_i} \right\rangle^2$$

$$h_i^{Melt}(T) = \Sigma_k^{nc} \langle A_k x_k \cdot T(K) + B_k x_k \rangle$$

$$h_i^{Glass}(T) = \Sigma_k^{nc} \left\langle a_k x_k \cdot T(K) + \frac{c_k x_k}{T(K)} + d_k x_k \right\rangle$$

CONSTRAINED MODEL

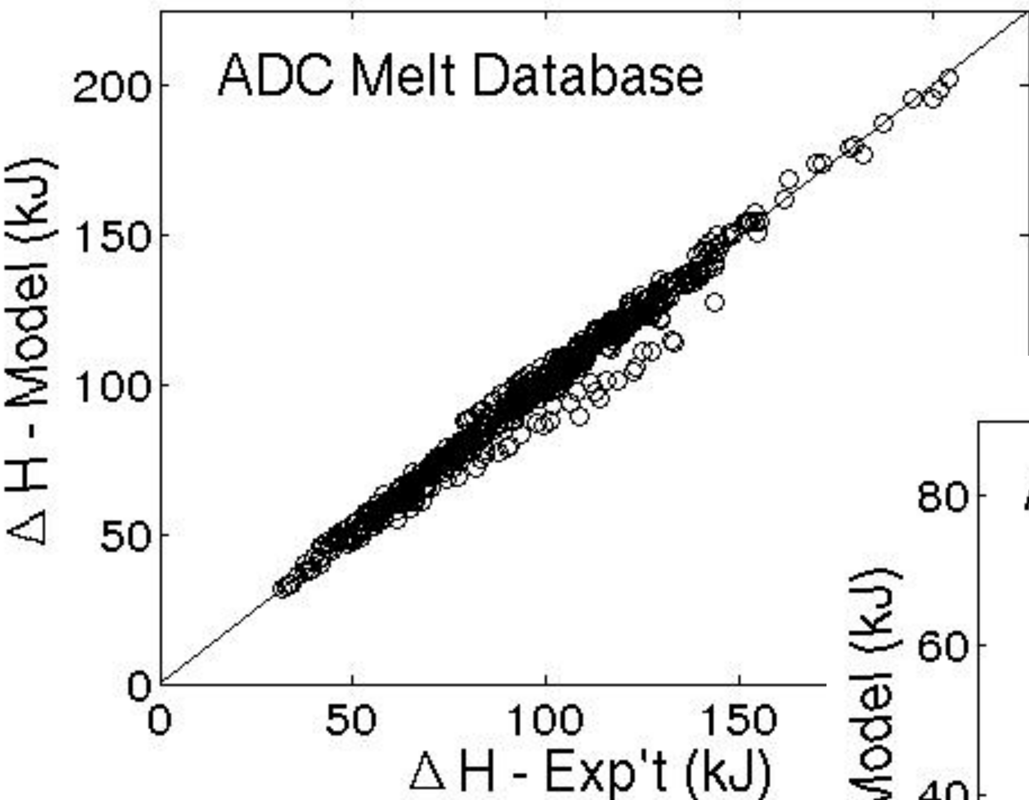
- Model equations for melts and glasses are UNCOUPLED
- Compositional coefficients are linearly independent
- Use Tg values as linear equality constraints
- Couples the coefficients for melts and glasses
- N < = RANK of compositional matrix (RANK =7)

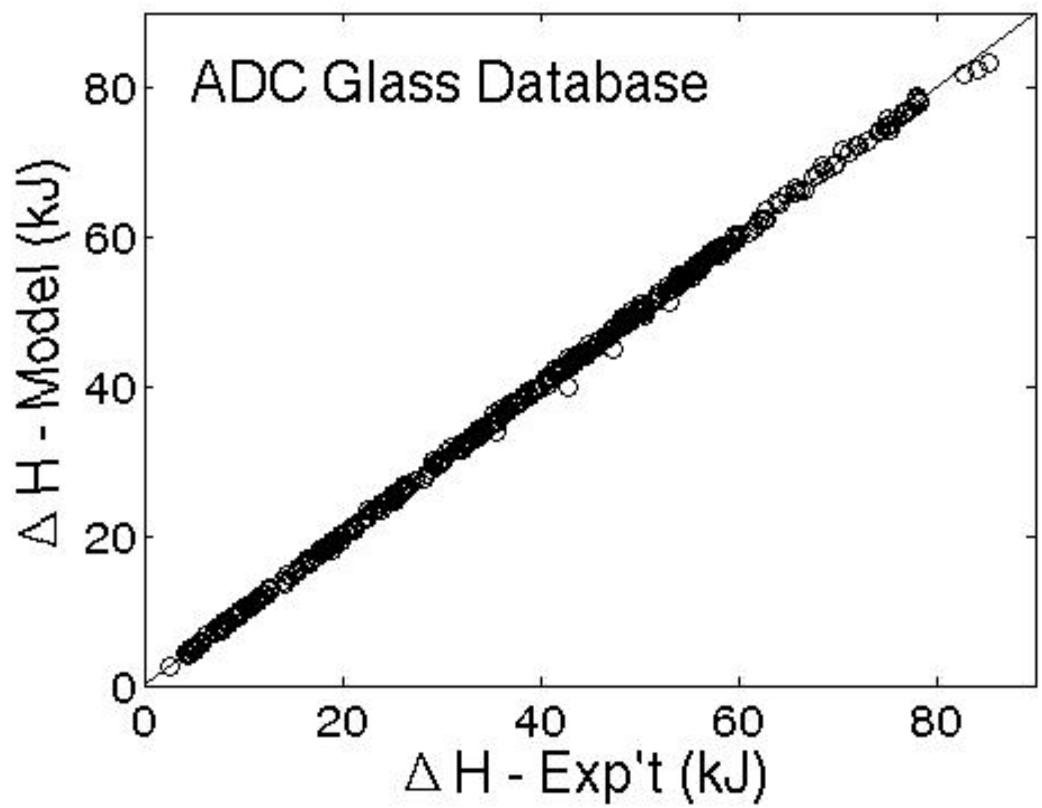
CONSTRAINT EQUATIONS

$$\Sigma_k^{nc} \langle (A_k - a_k) \cdot x_k \rangle \cdot Tg^2 + \Sigma_k^{nc} \langle (B - d) x_k \rangle \cdot Tg - \Sigma_k^{nc} (c_k x_k) = 0$$

ALLOWS use of 7 independent estimates of Tg
Compositions must be LINEARLY INDEPENDENT

MODEL vs. DATA



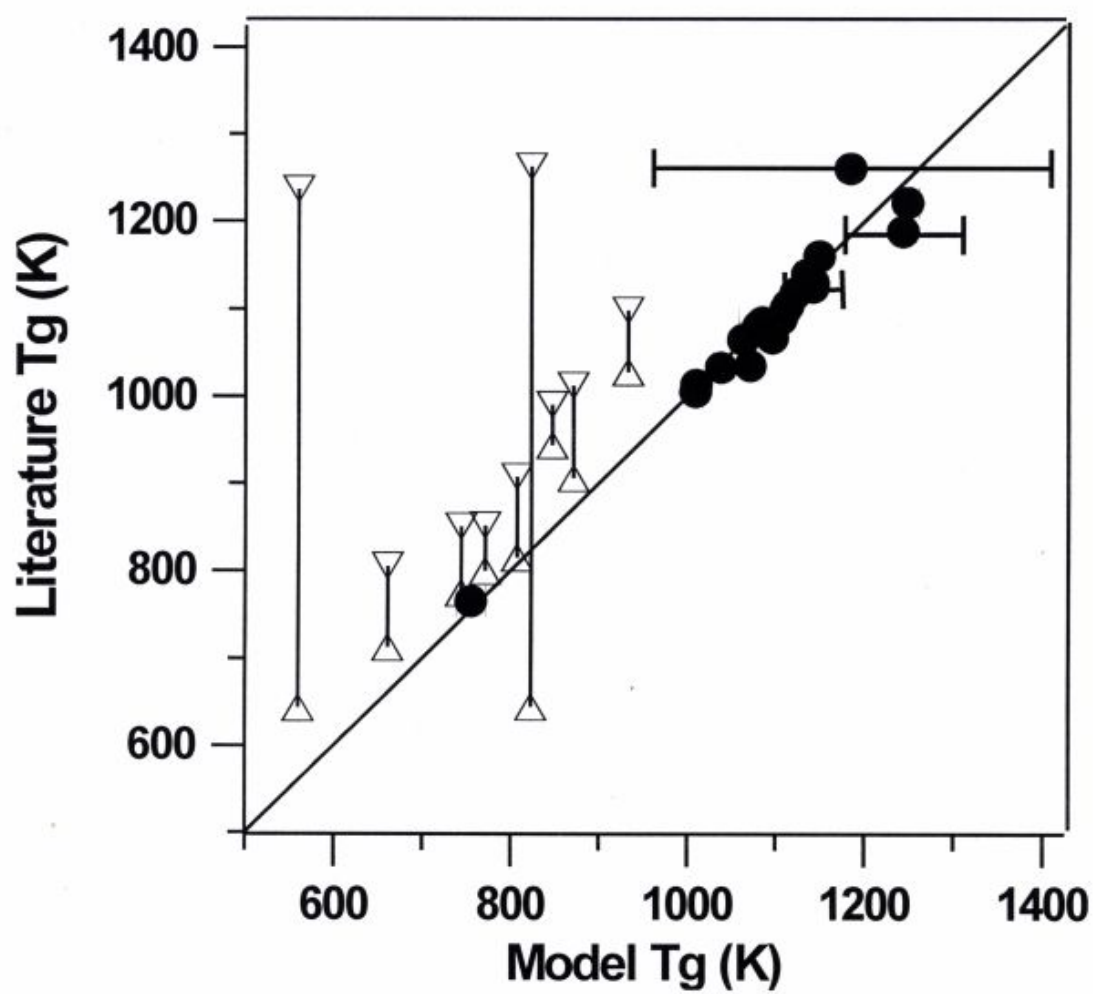


$$Tg(K) = \frac{-\beta(x) \pm \sqrt{\beta(x)^2 - 4\cdot\alpha(x)\cdot\gamma(x)}}{2\cdot\alpha(x)}$$

$$\alpha(x) = \Sigma_{i=1}^{n}(A_i - a_i)\cdot x_i$$

$$\beta(x) = \Sigma_{i=1}^{n}(B_i - d_i)\cdot x_i$$

$$\gamma(x) = -\Sigma_{i=1}^{n}(c_i \cdot x_i)$$



APPLICATIONS & TAKE AWAYS

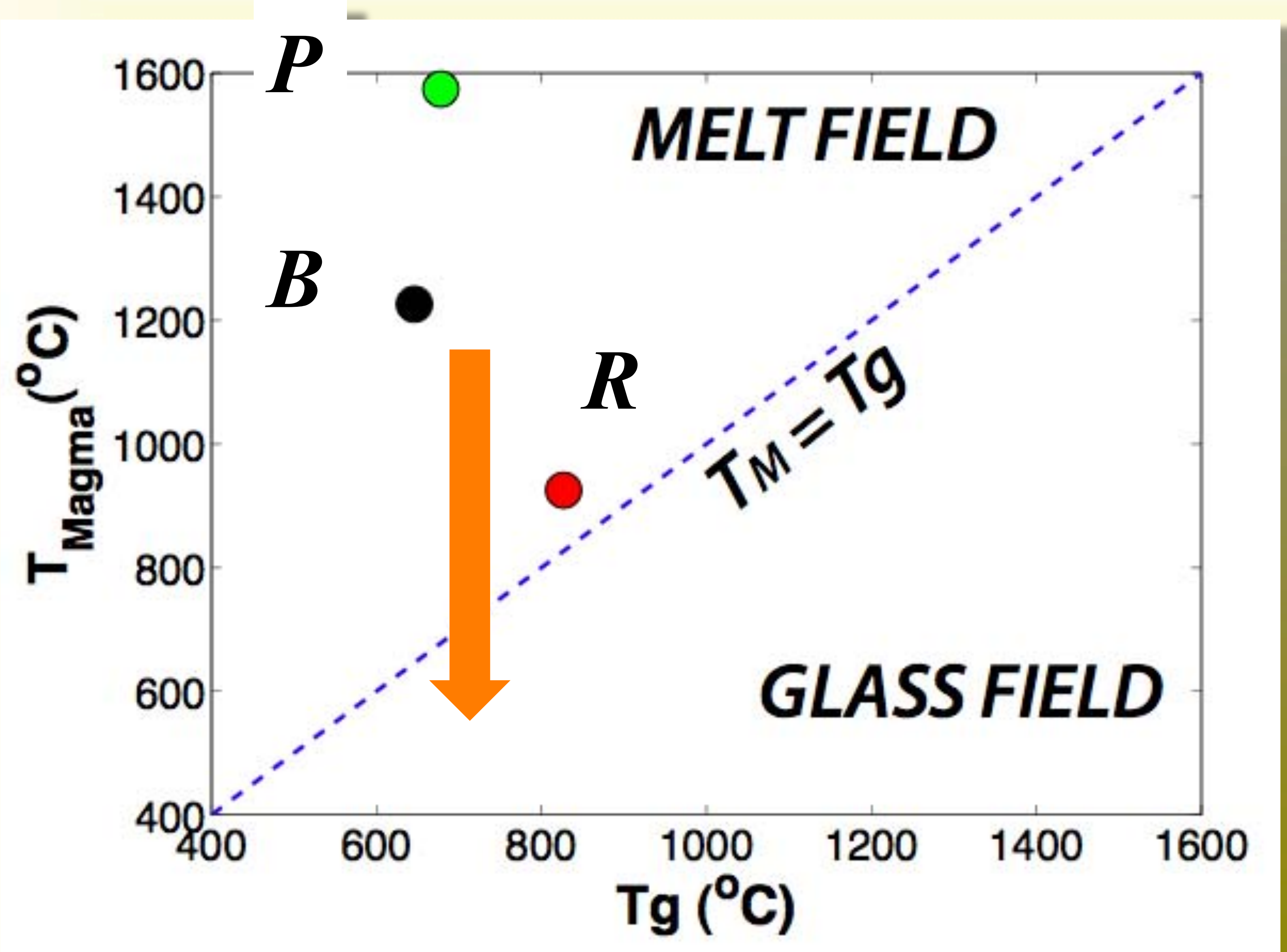
A) **TRACK T_{magma} vs. Tg** during magmatic processes such as fractional crystallization, vesiculation, melting.

B) **TERMINATION OF LIQUID LINE OF DESCENT** Where liquid line of descent (e.g., T-X path) intersects Tg of the melt, glass forms and terminates many processes.

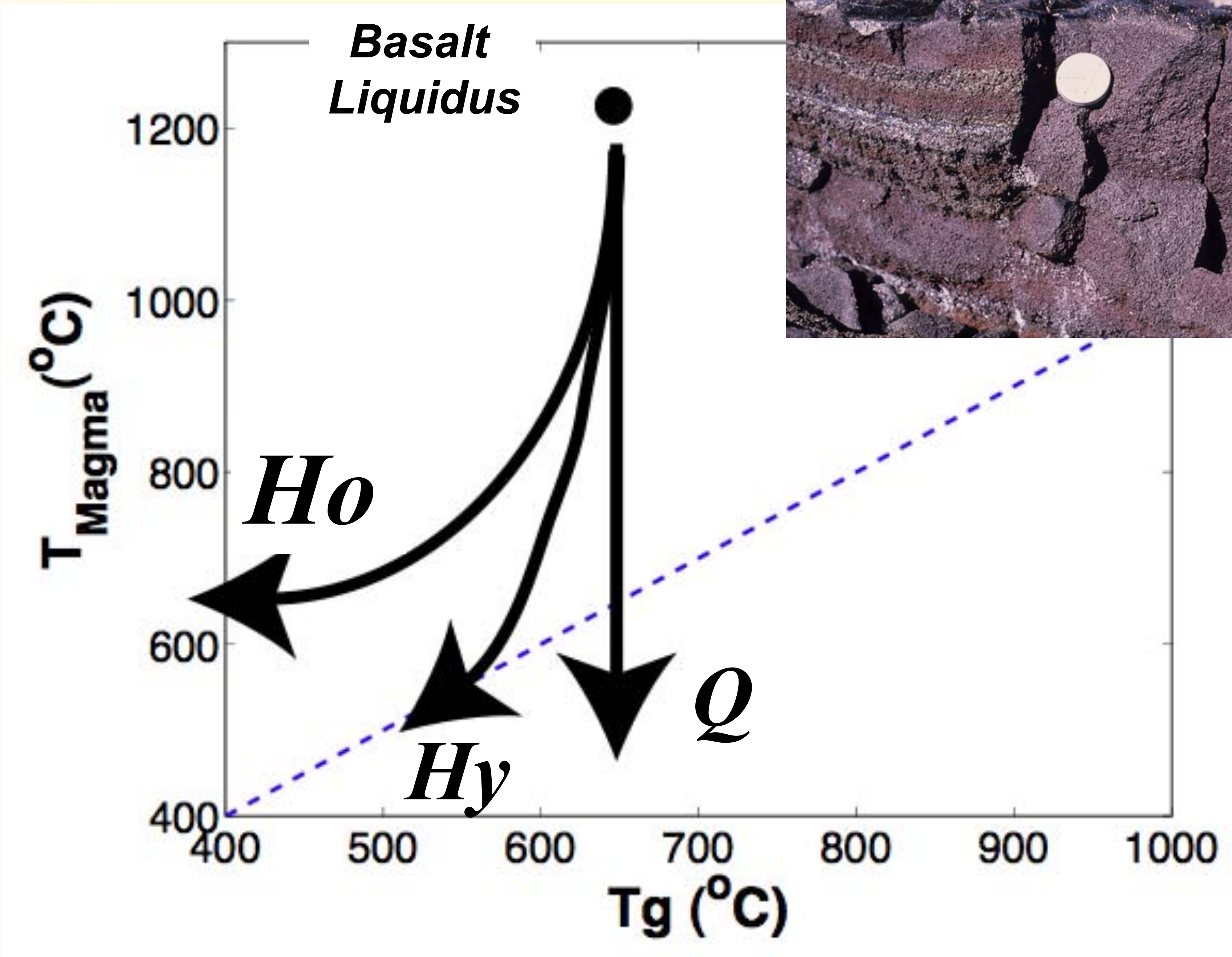
C) **GEOTHERMOMETRY**

Glass compositions converted to pre-eruption T_{min}.

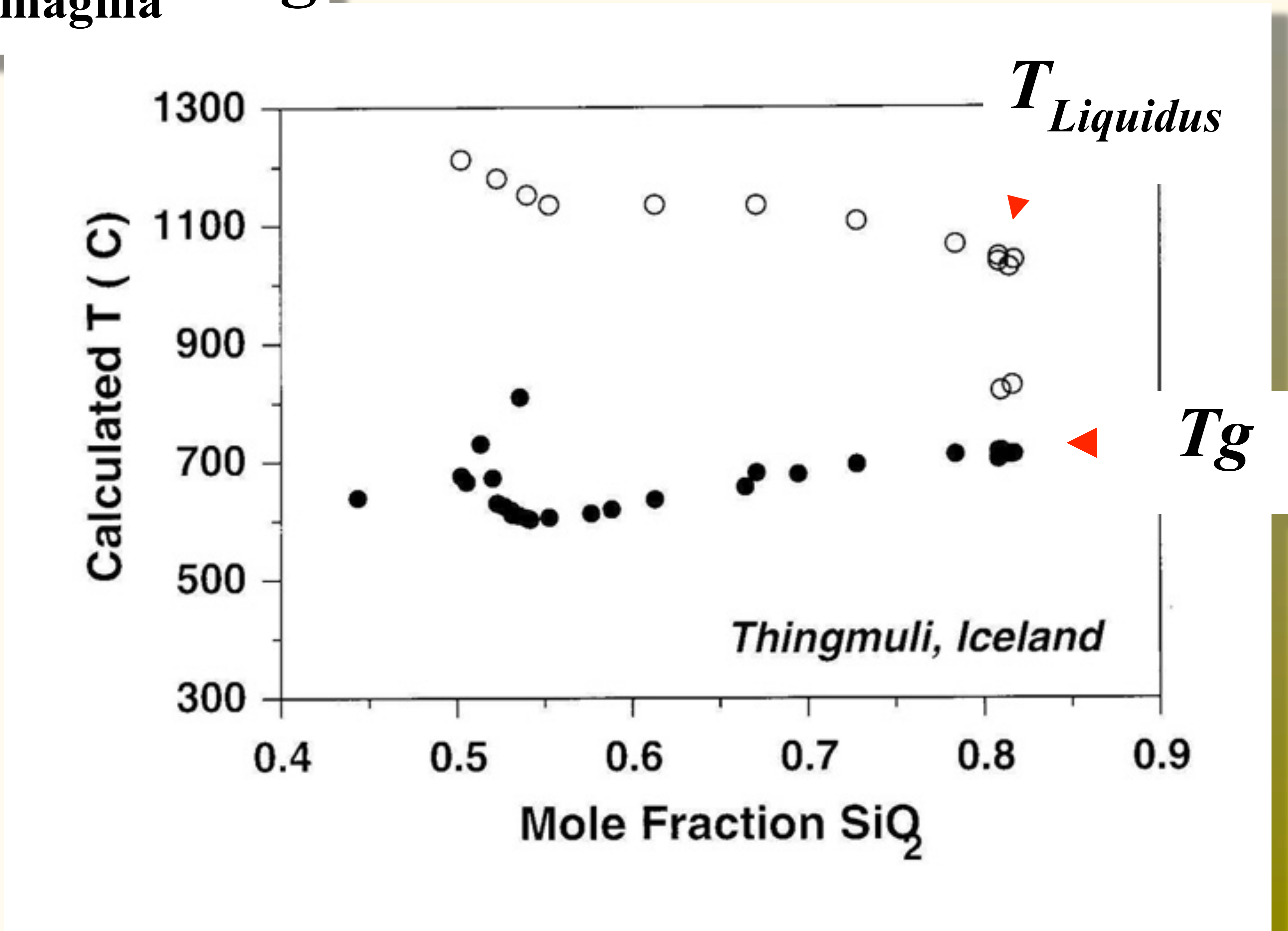
TG - Melt Composition



GLASS FORMING PATHS



T_{magma} - Tg

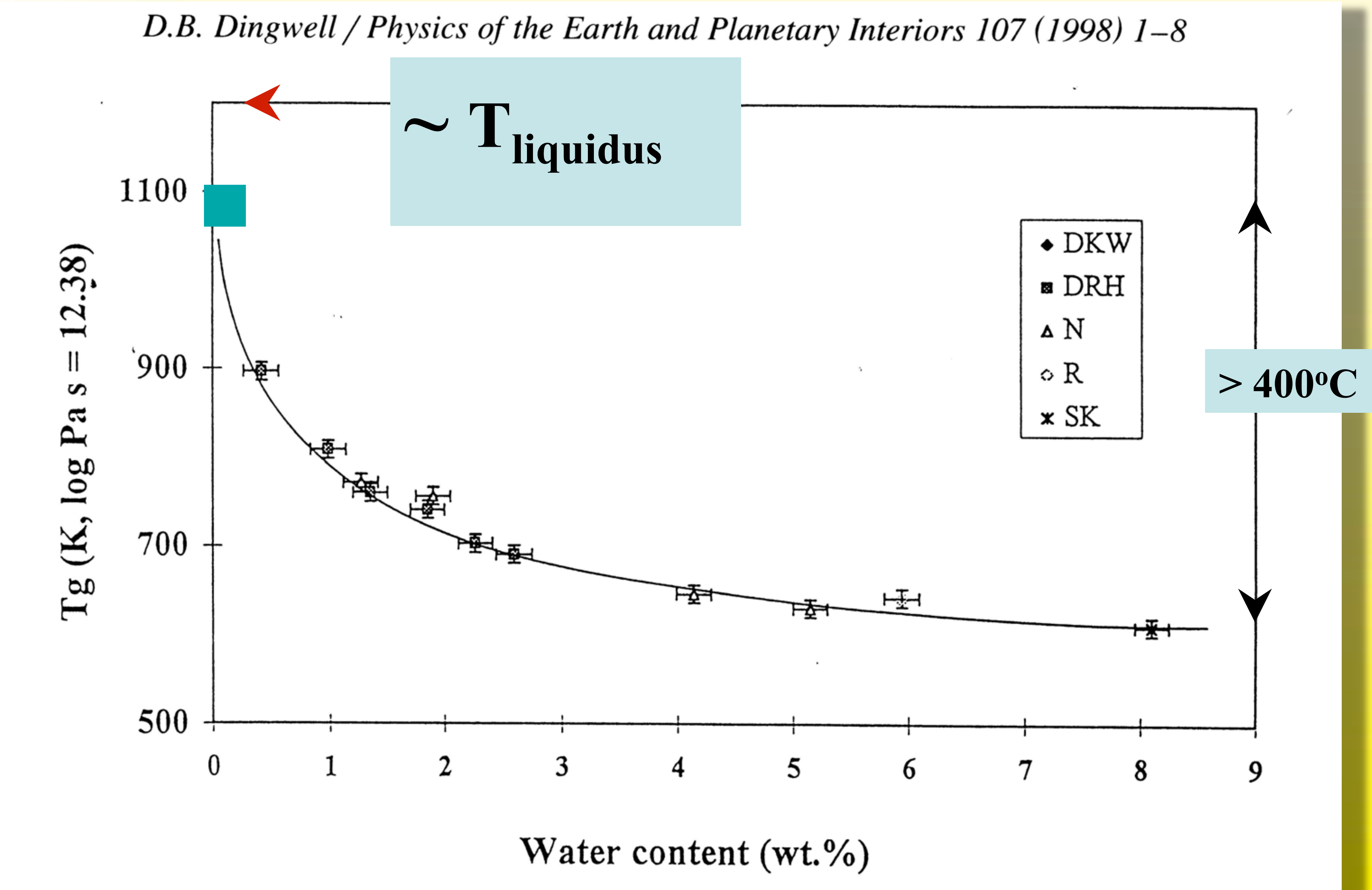


$T_{Liquidus}$
Tg
1300
1100
900
700
500
300
Calculated T (C)
Thingmuli, Iceland
0.4
0.5
0.6
0.7
0.8
0.9
Mole Fraction SiO_2

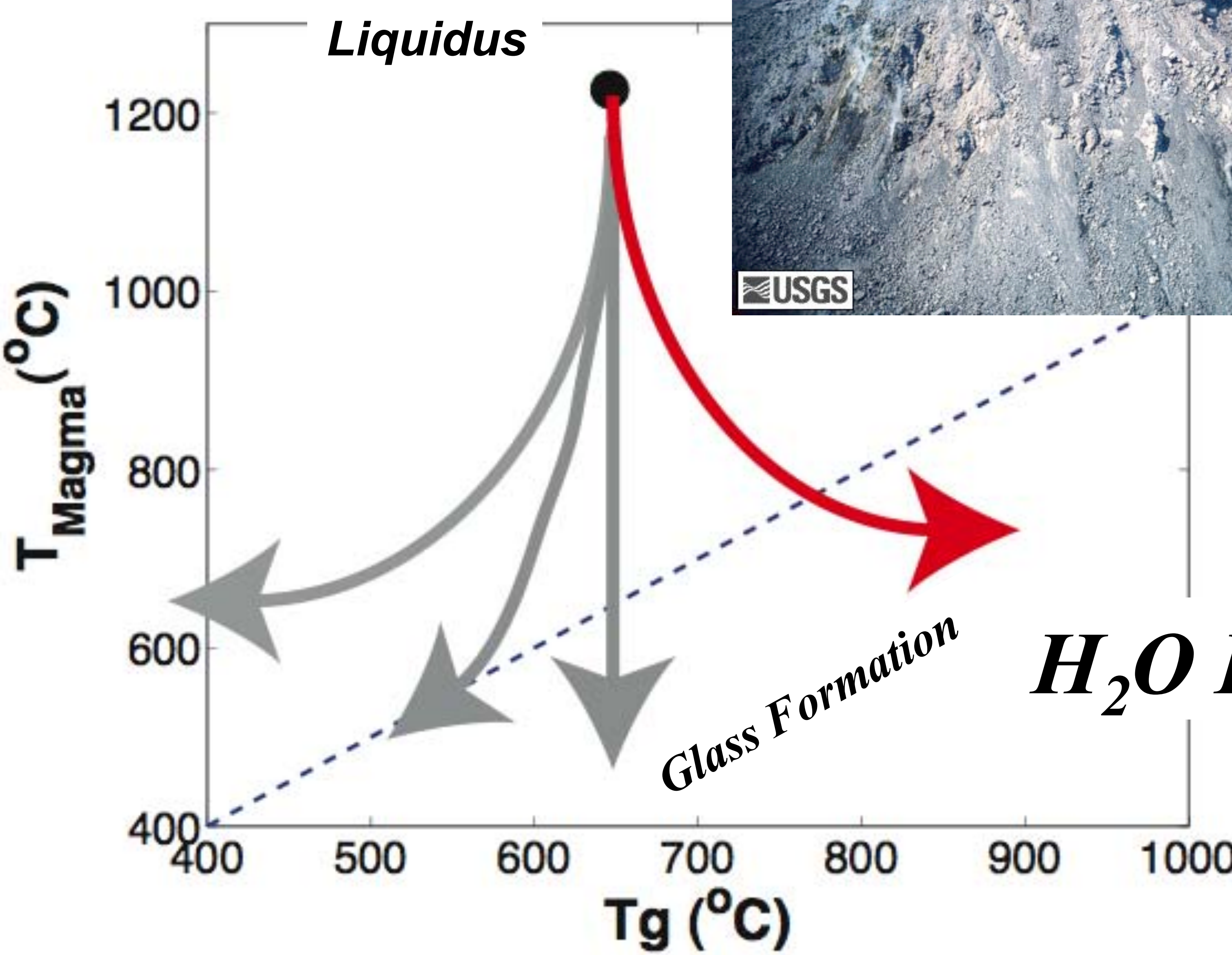
Caveat Emptor (Construction Zone)

Tg Depression by H_2O

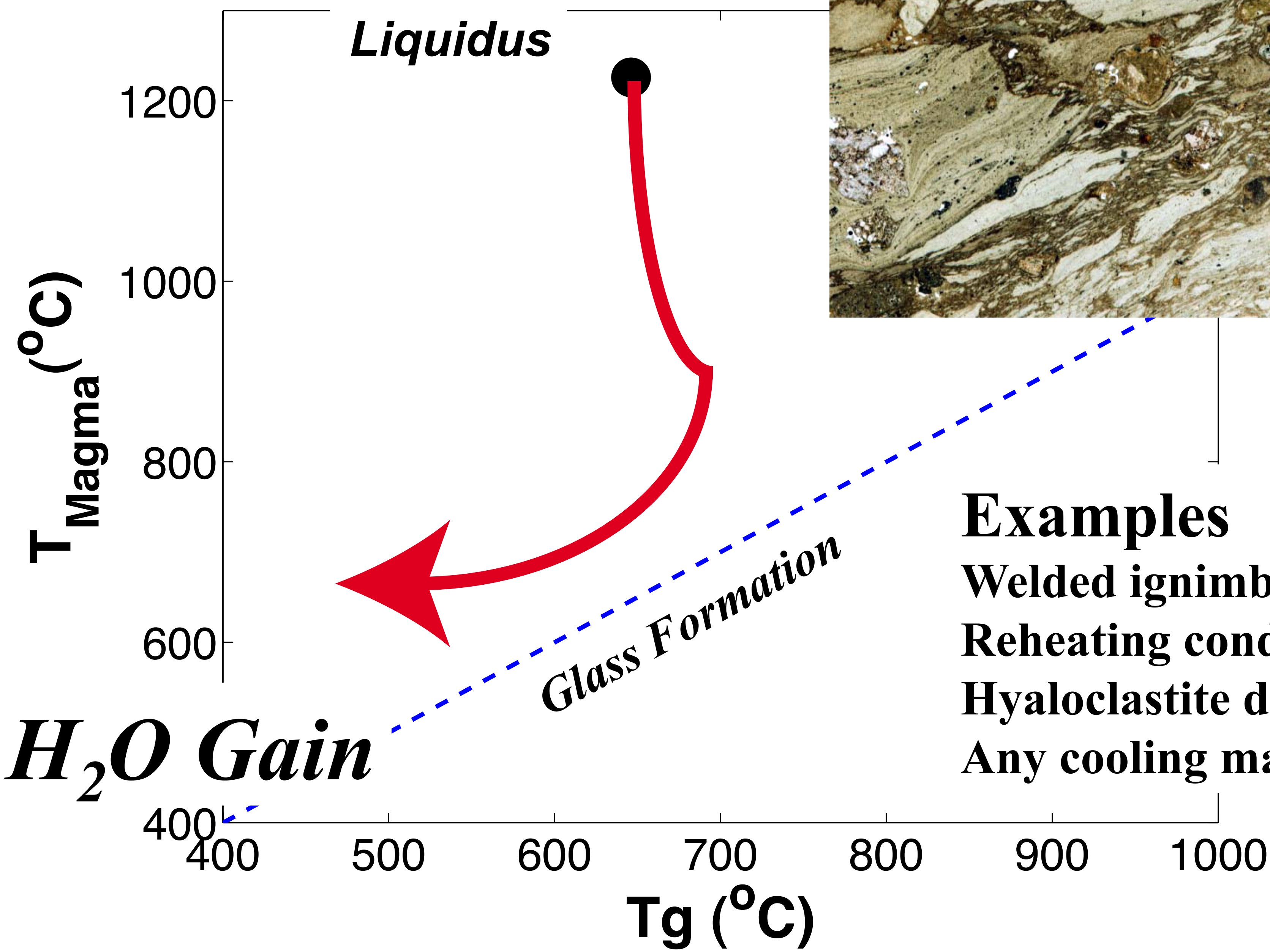
Need partial molar H_{H2O} melts/glasses

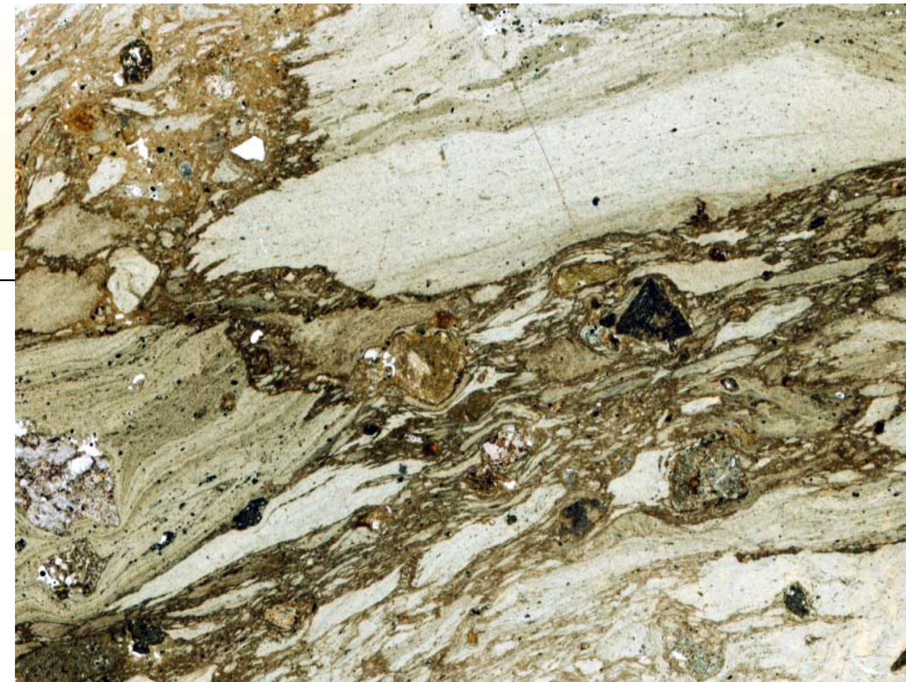


Tg & DEGASSING



Tg & REHYDRATION





Examples

Welded ignimbrites
Reheating conduit rocks
Hyaloclastite deposits
Any cooling magma

SUMMARY

Glass formation is a boundary between changing environmental states.

A) Above Tg, rates of crystallization & vesiculation are sufficiently fast to affect magmatic processes

B) Where liquid lines of decent intersect the Tg of the melt, glass forms and many processes cease.

MIXING & ASCENT .... Hmm ??