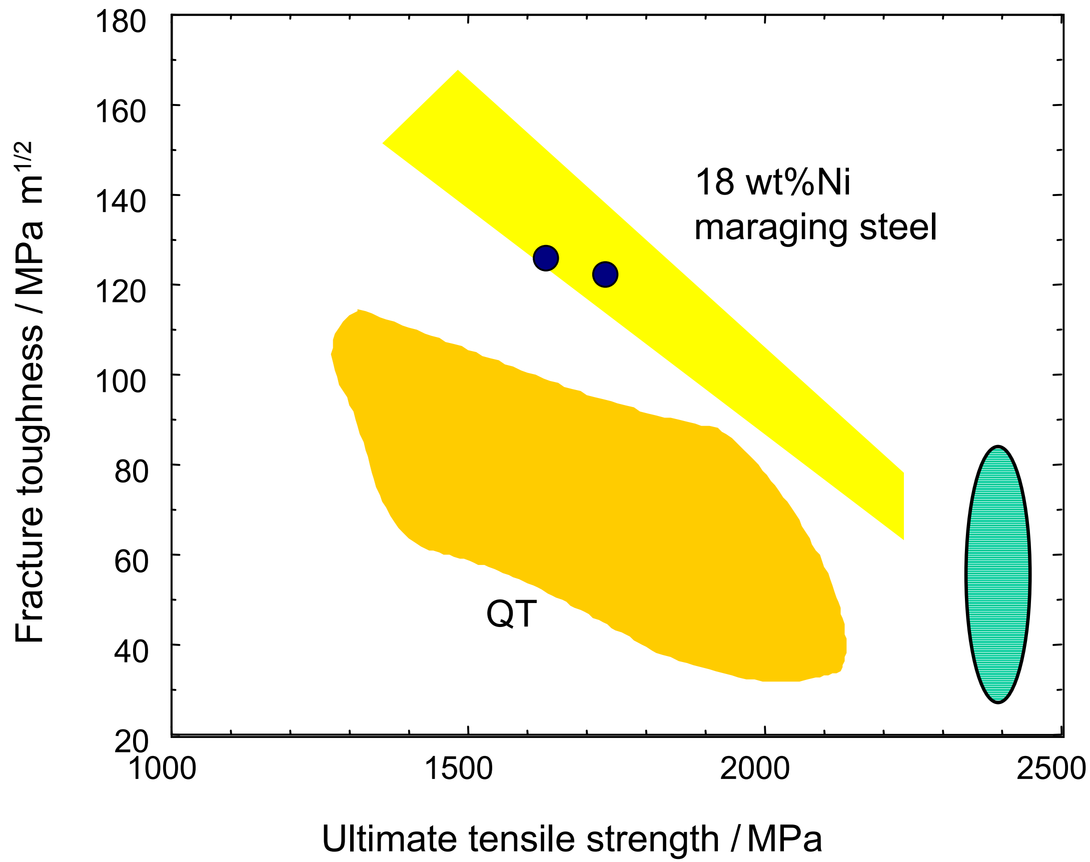
Very Strong, Low Temperature Bainite



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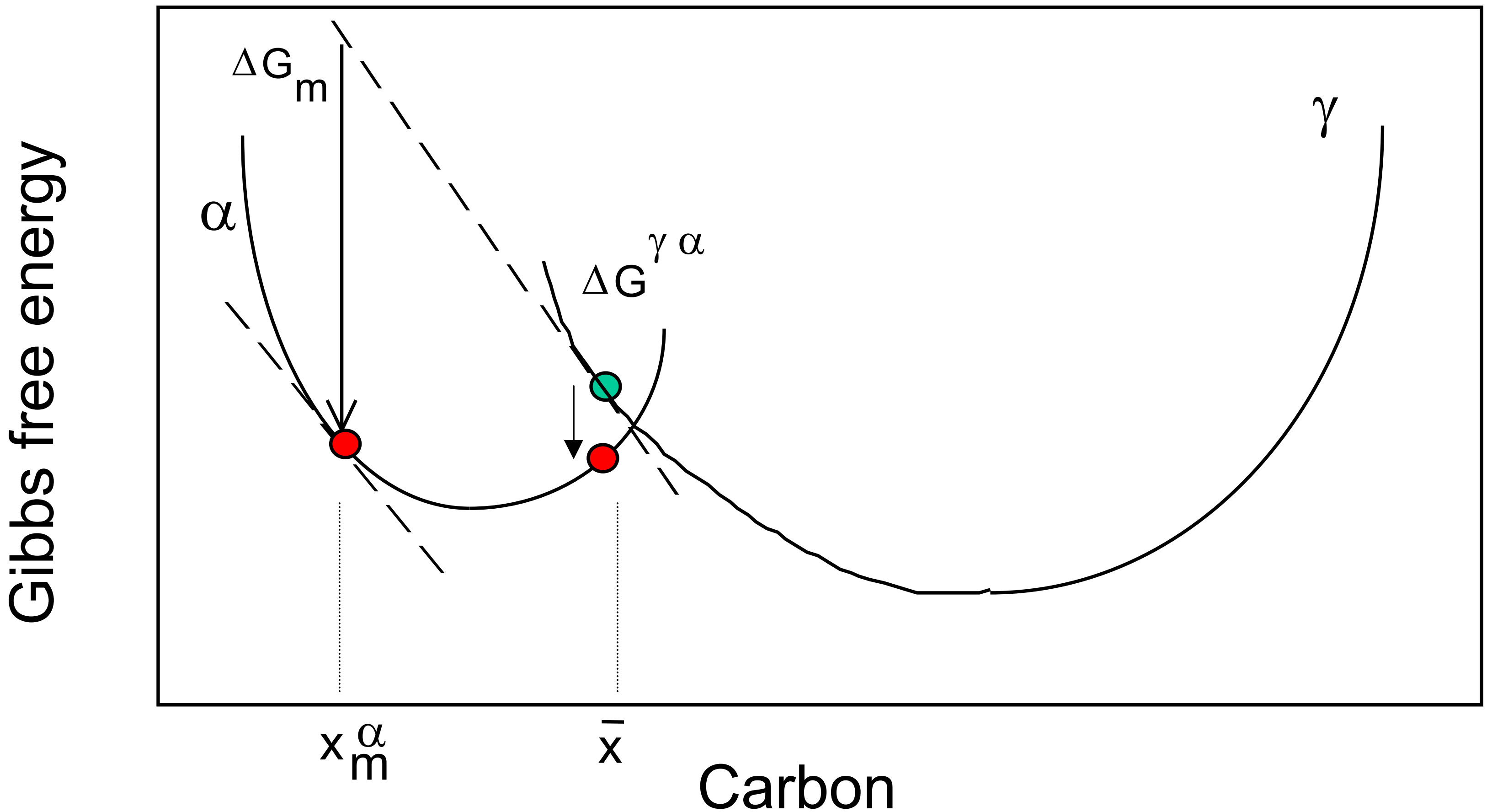
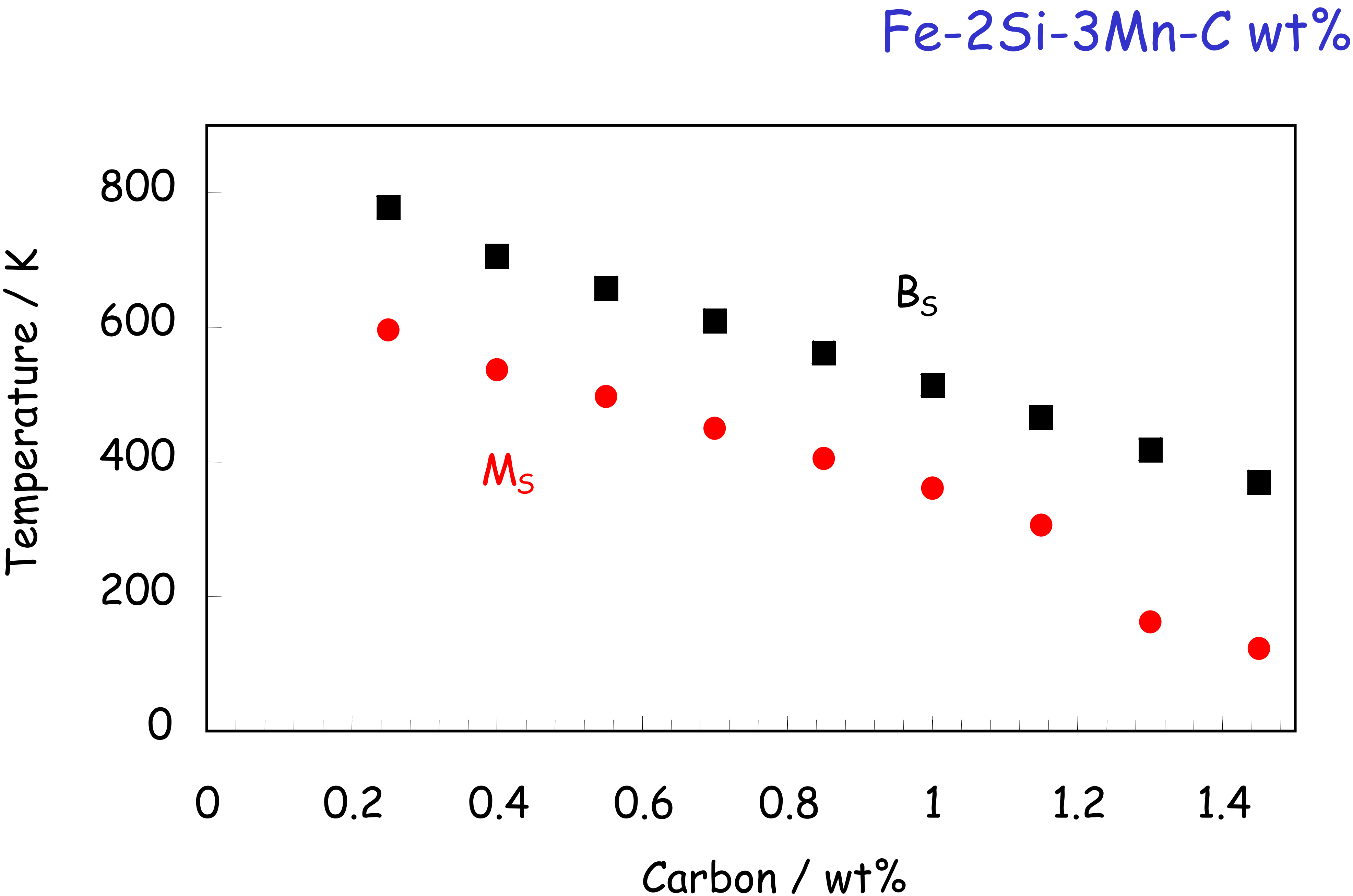
theory



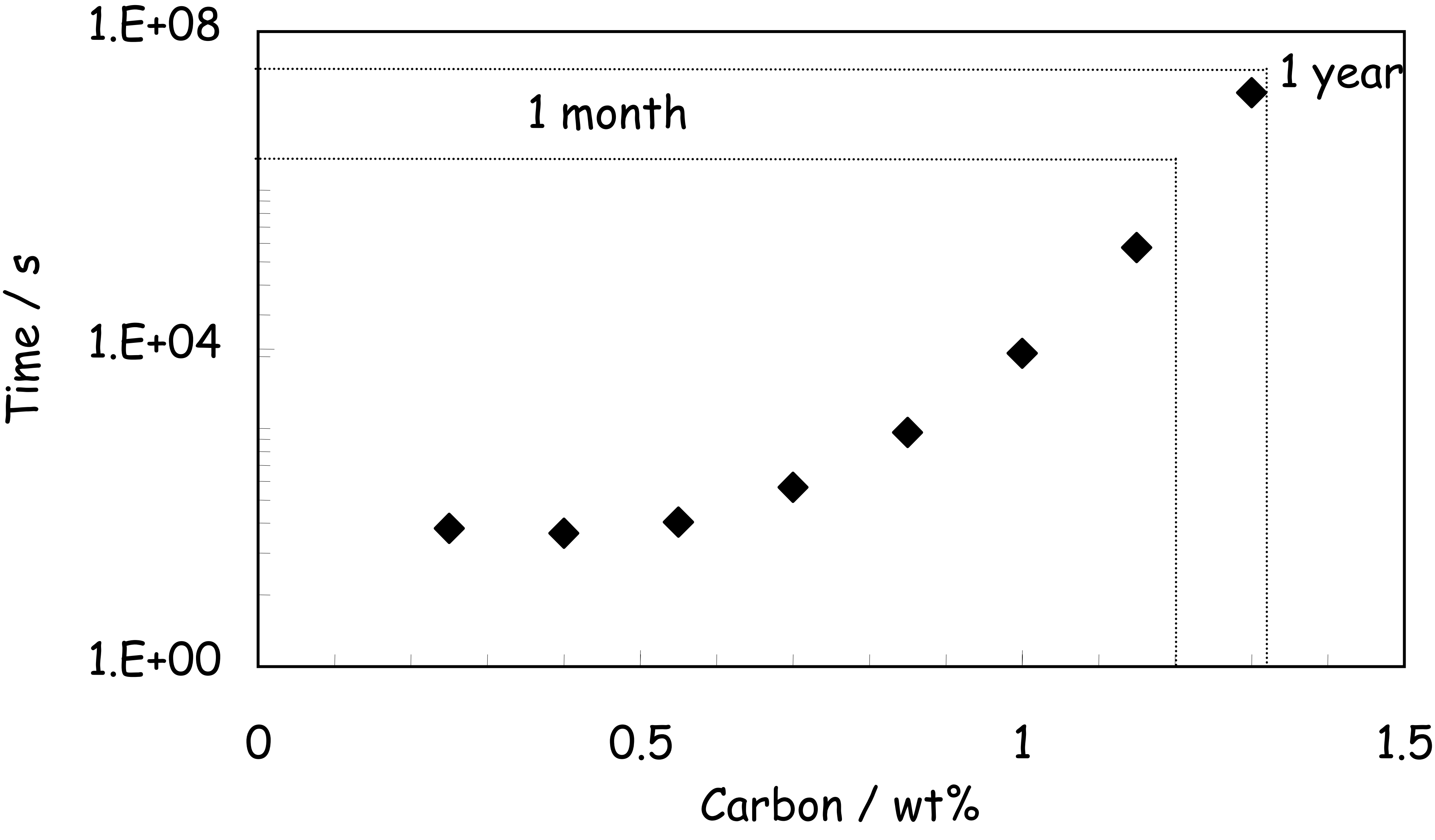
Bainite-start temperature

$$\Delta G_m < G_N$$

$$\Delta G^{\gamma \rightarrow \alpha} < -G_{SB}$$


Fe-2Si-3Mn-C wt%
Temperature / K
800
600
400
200
0
B_S
M_S
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Carbon / wt%

Fe-2Si-3Mn-C wt%



Low transformation temperature

Reasonable transformation time

Bainitic hardenability

Elimination of cementite

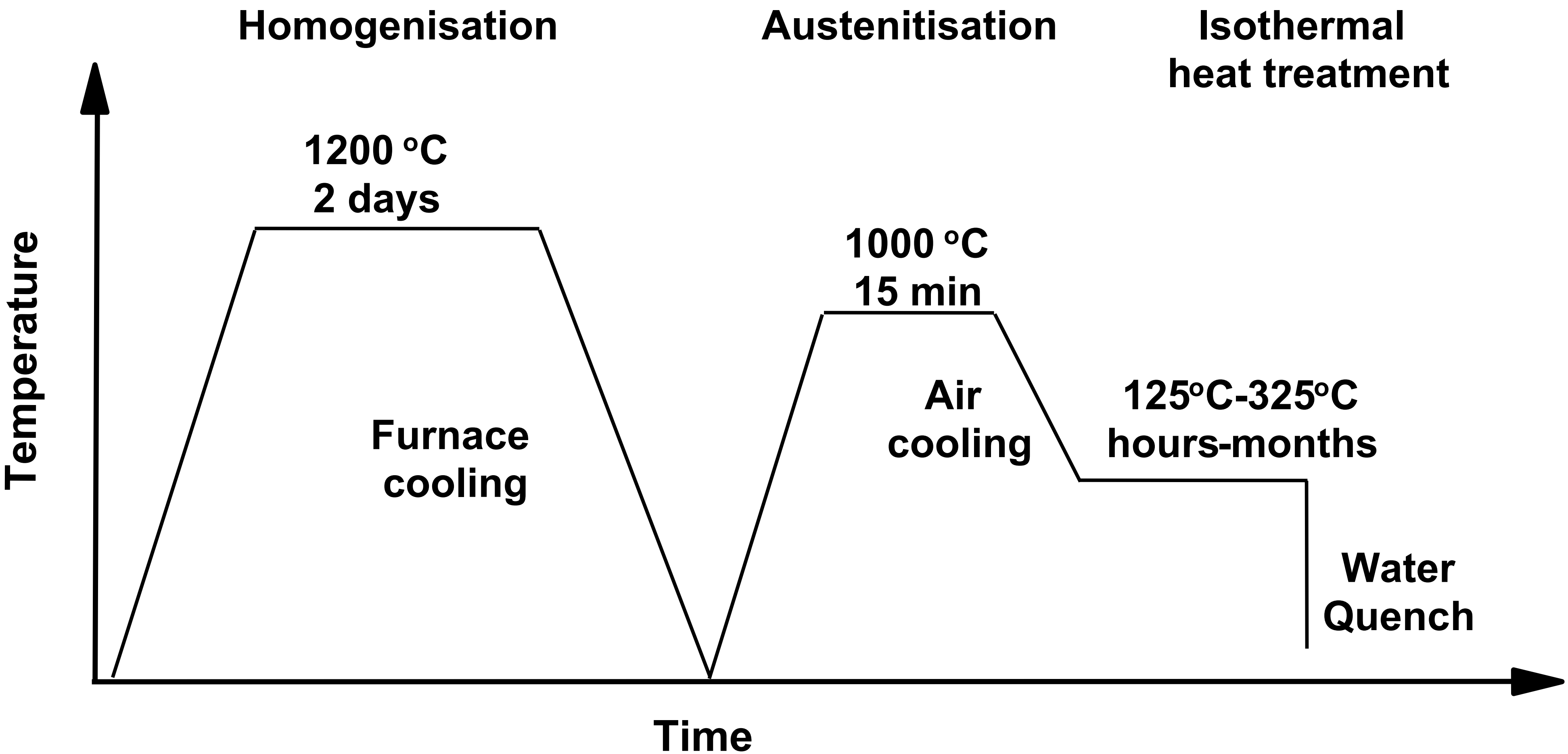
Austenite grain size control

Avoidance of temper embrittlement

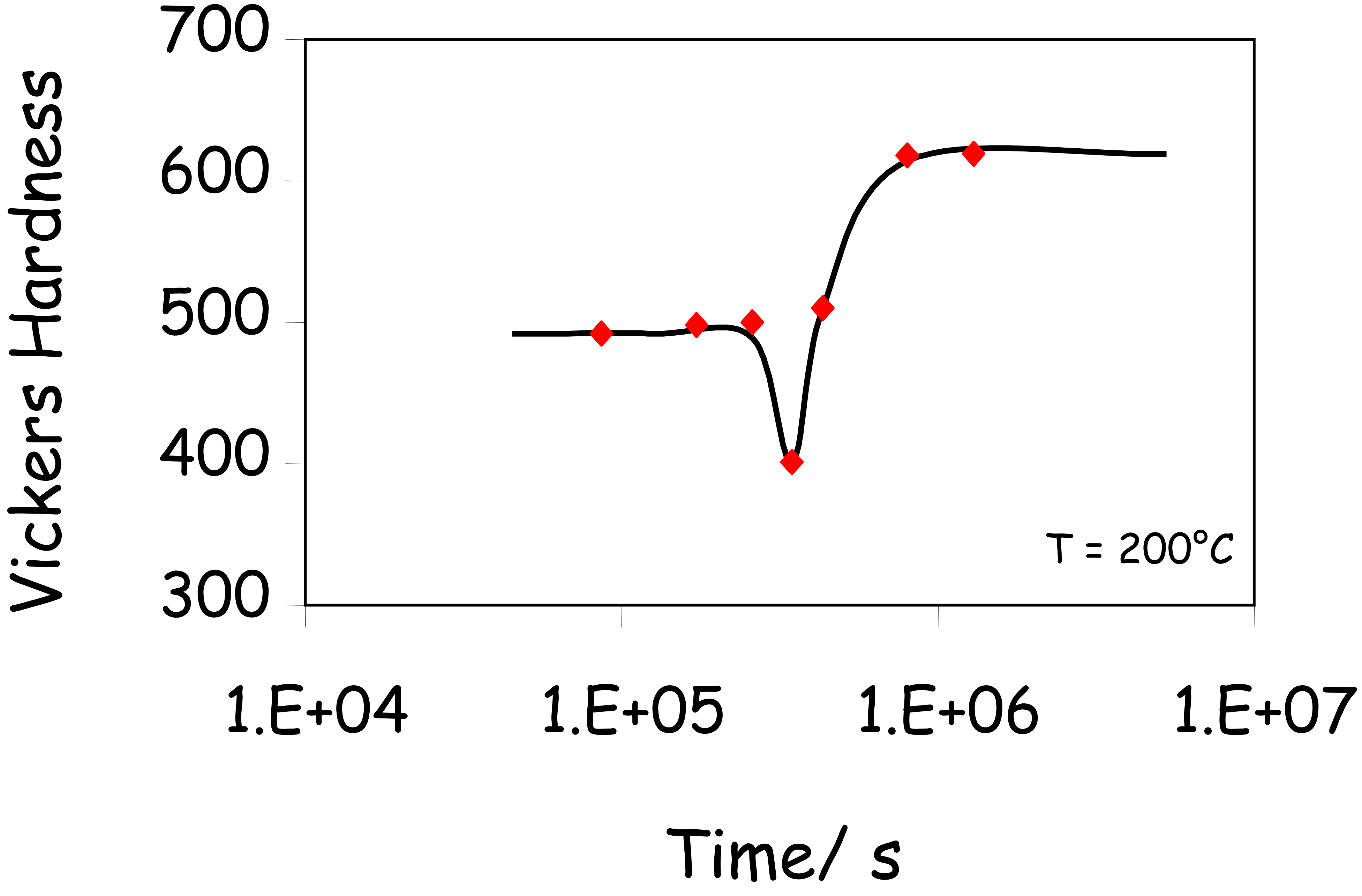
wt%

C	Si	Mn	Mo	Cr	V	P
0.98	1.46	1.89	0.26	1.26	0.09	< 0.002

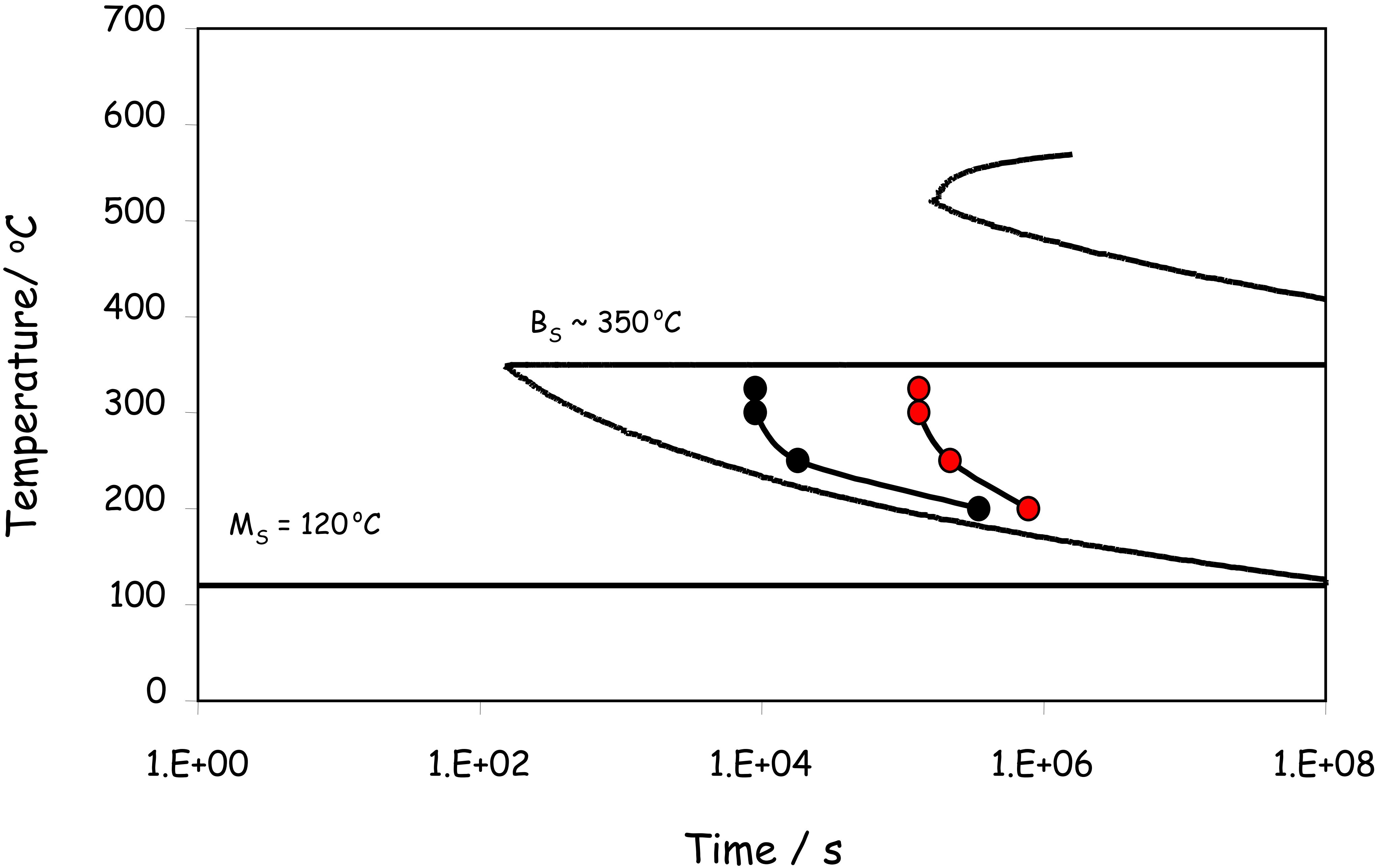
Procedure



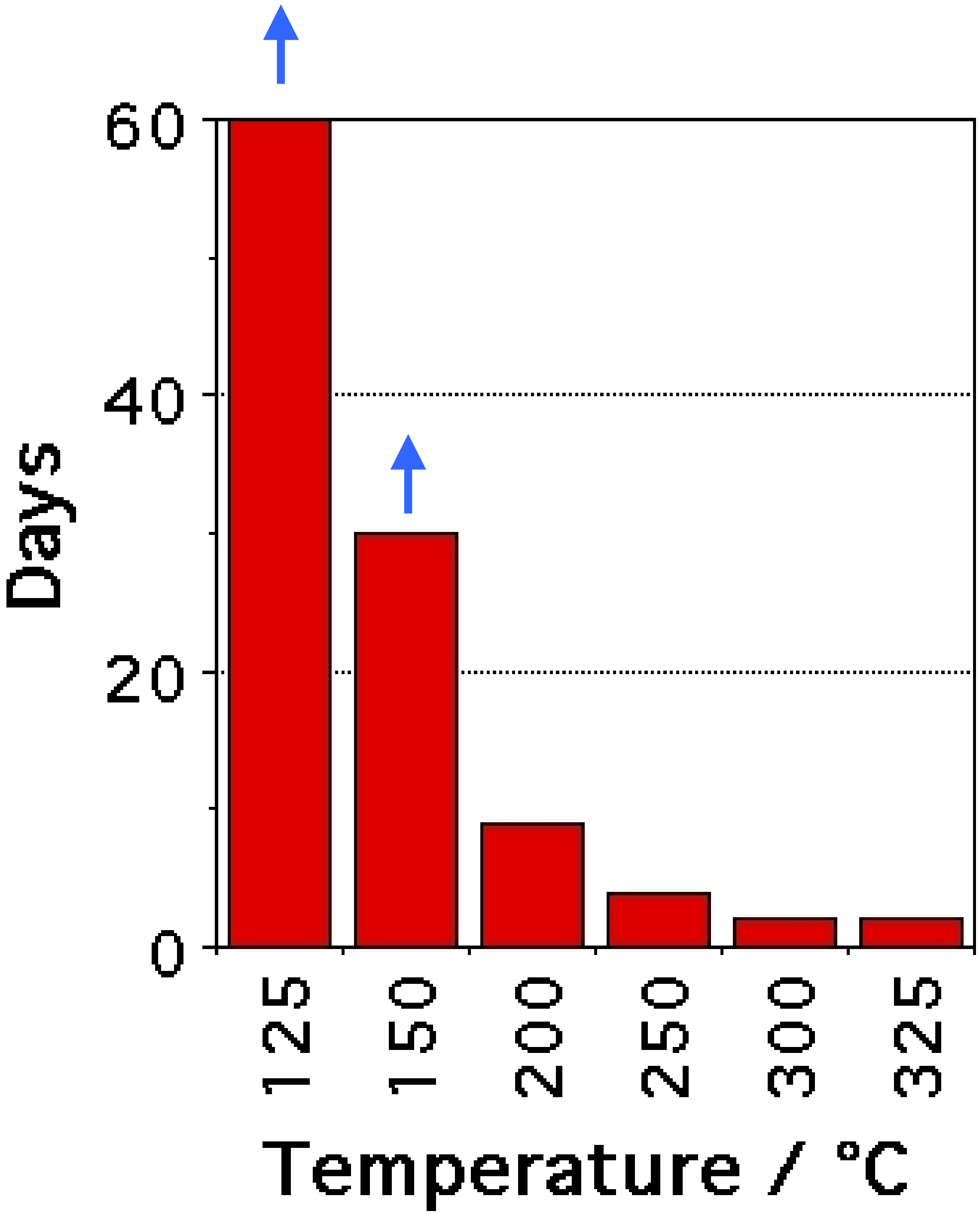
Homogenisation
Austenitisation
Isothermal
heat treatment
1200 °C
2 days
1000 °C
15 min
Temperature
Furnace
cooling
Air
cooling
125°C-325°C
hours-months
Water
Quench
Time



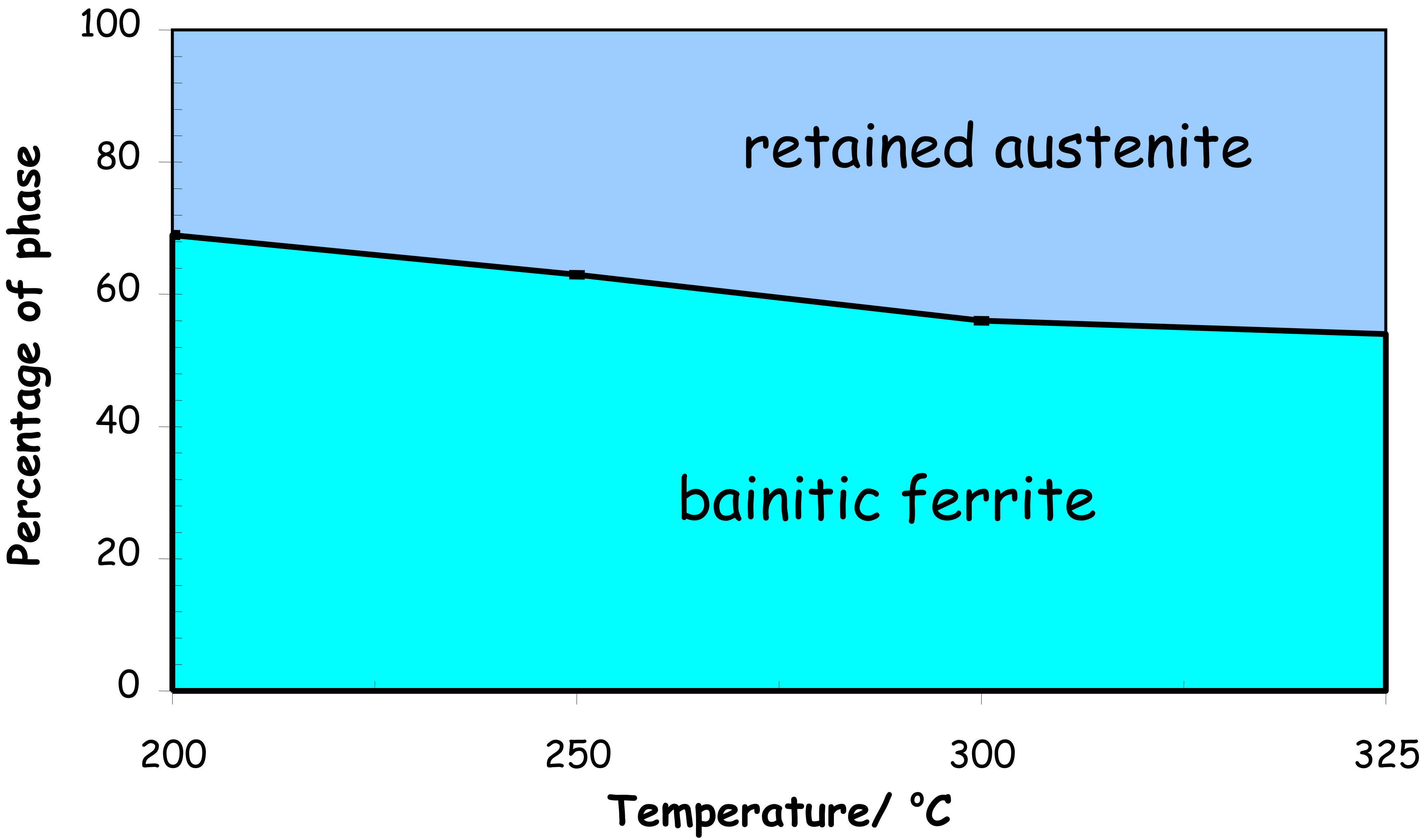
Vickers Hardness
700
600
500
400
300
T = 200°C
1.E+04
1.E+05
1.E+06
1.E+07
Time/ s



Temperature/ °C
700
600
500
400
300
200
100
0
B_S ~ 350°C
M_S = 120°C
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Time / s

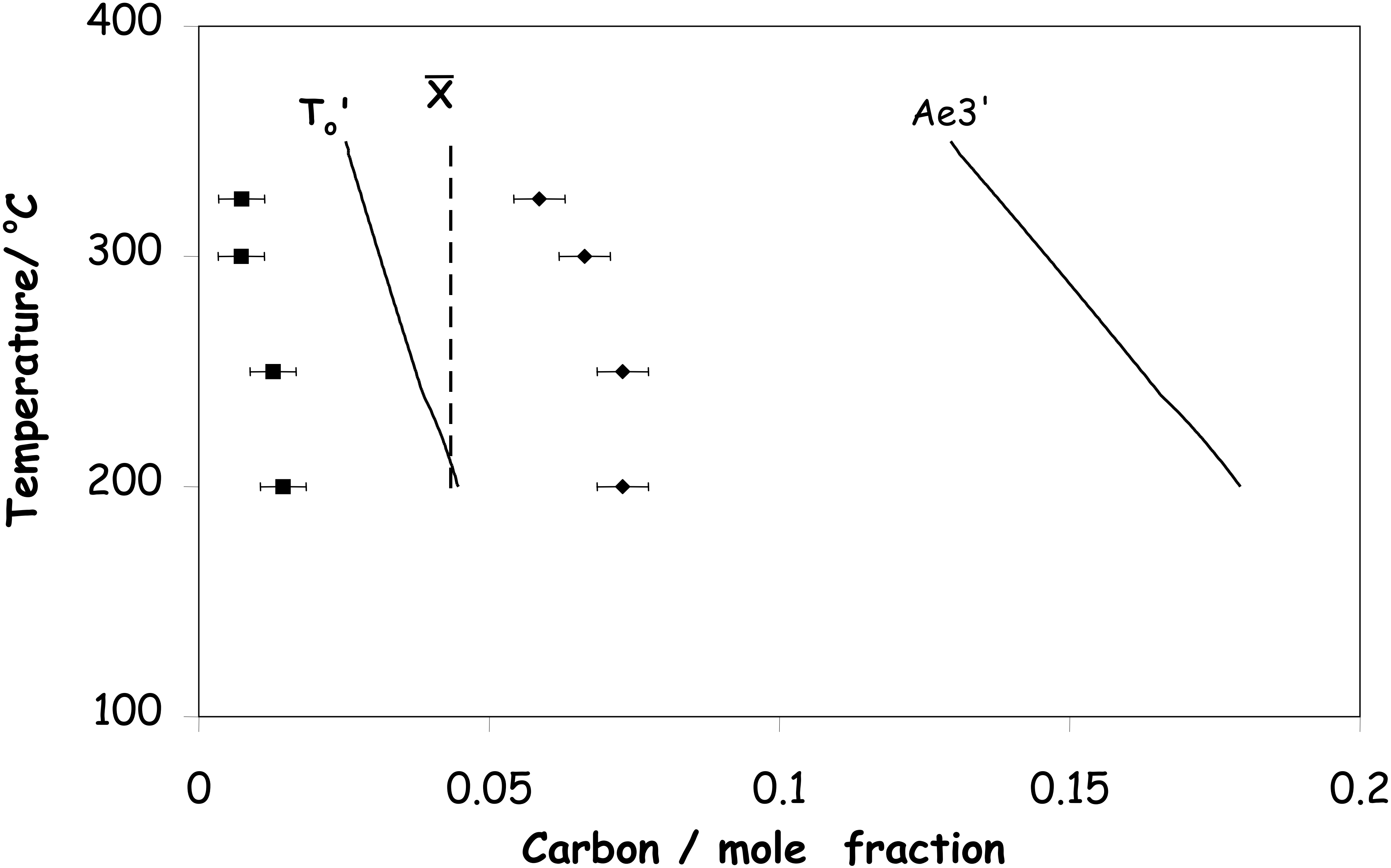


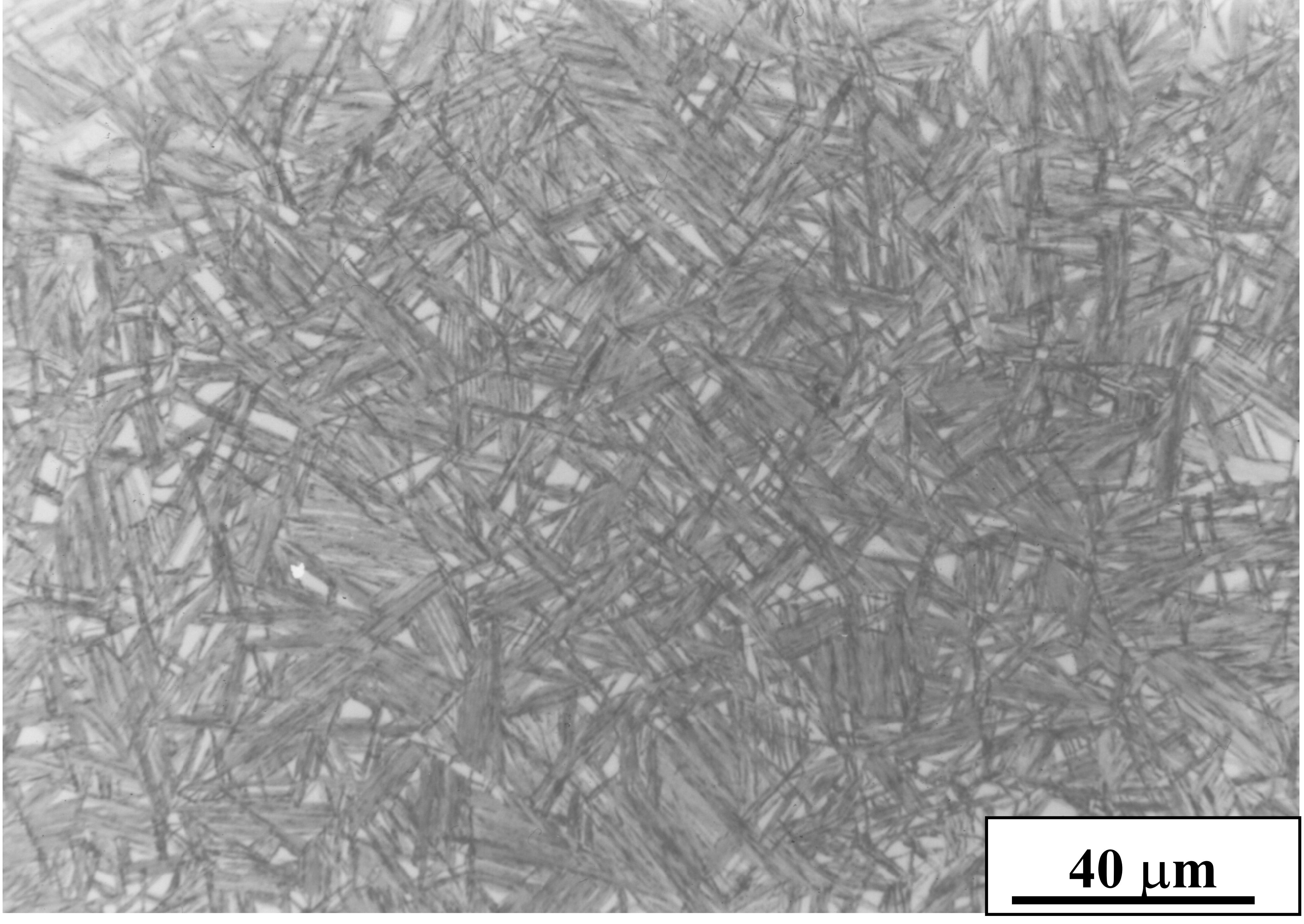
60
40
20
0
Days
125
150
200
250
300
325
Temperature / °C

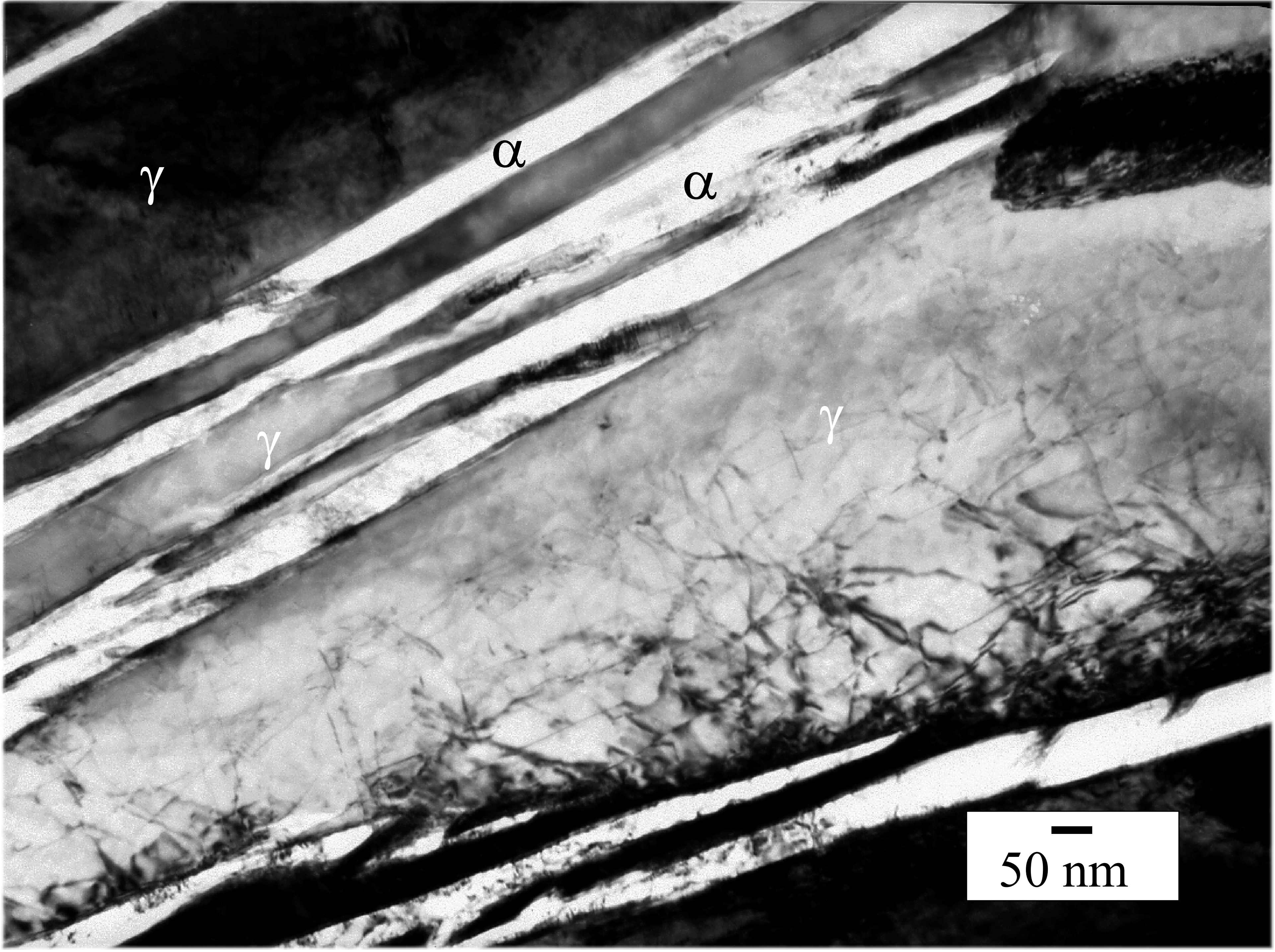


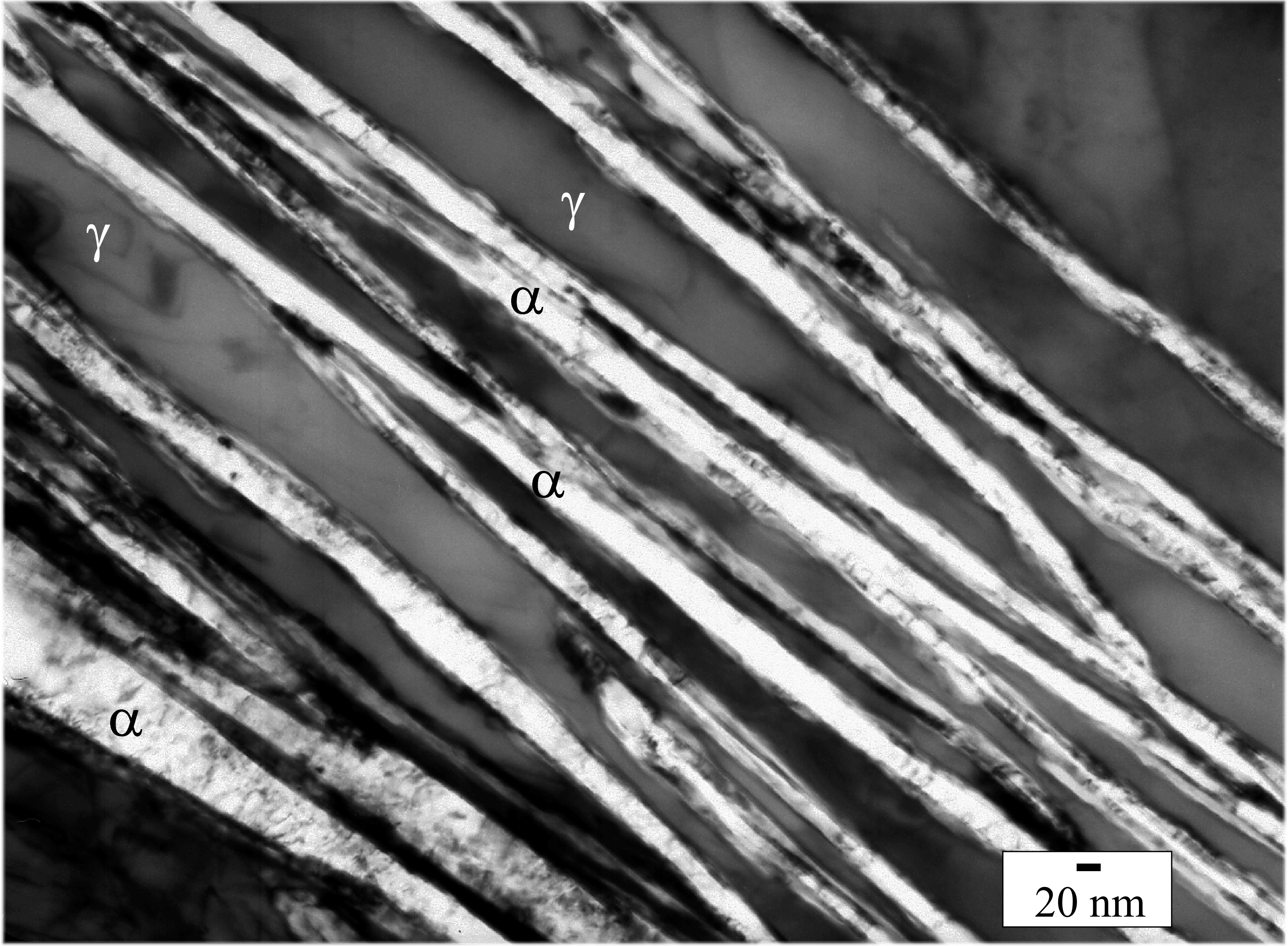
retained austenite
bainitic ferrite
Percentage of phase
100
80
60
40
20
0
200
250
300
325
Temperature/ °C

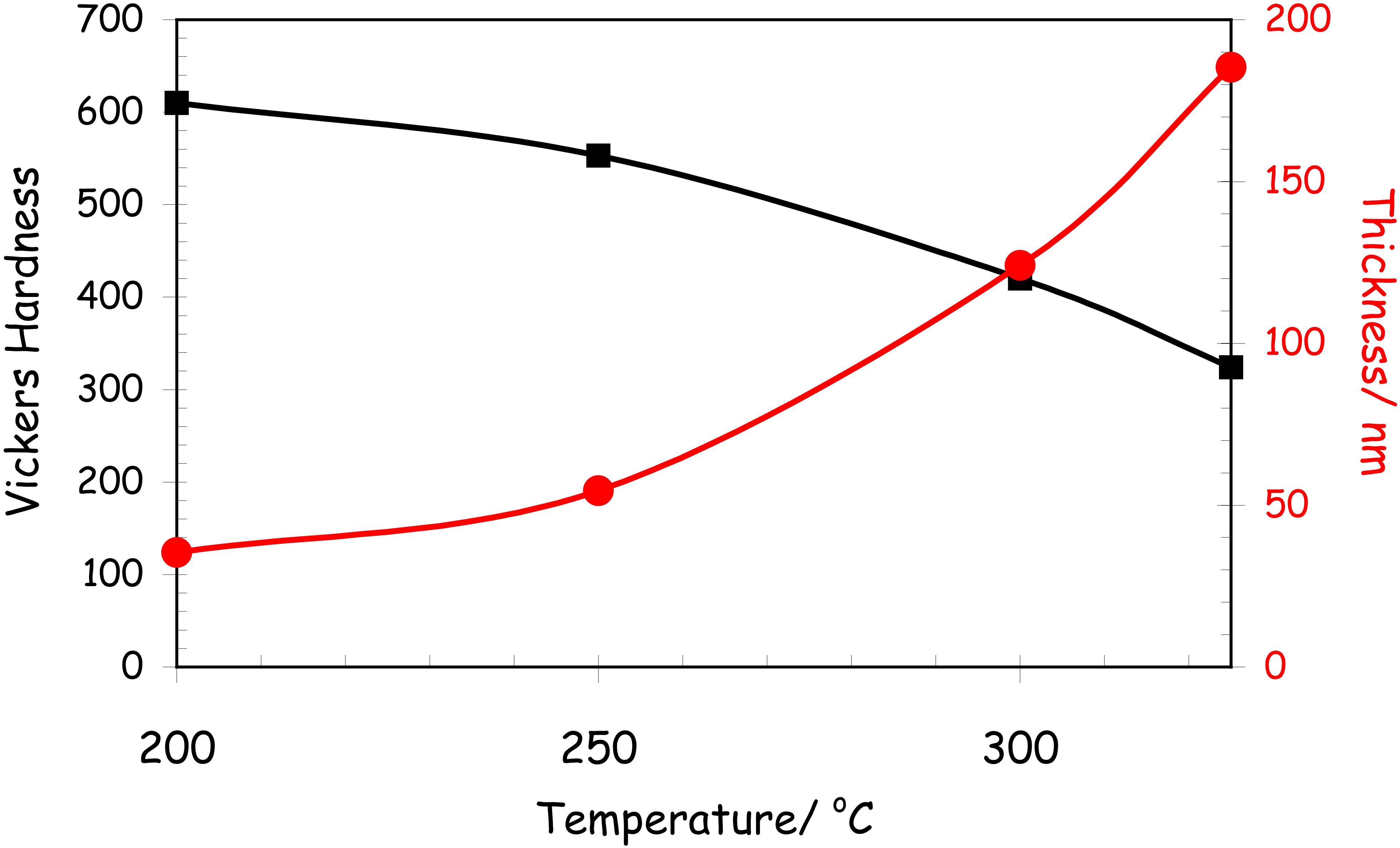
Incomplete Reaction Phenomena




40 μm


γ
α
α
γ
γ
50 nm


γ
γ
α
α
α
20 nm



700
600
500
400
300
200
100
0
Vickers Hardness
200
150
100
50
0
Thickness/ nm
200
250
300
Temperature/ °C

Conclusions

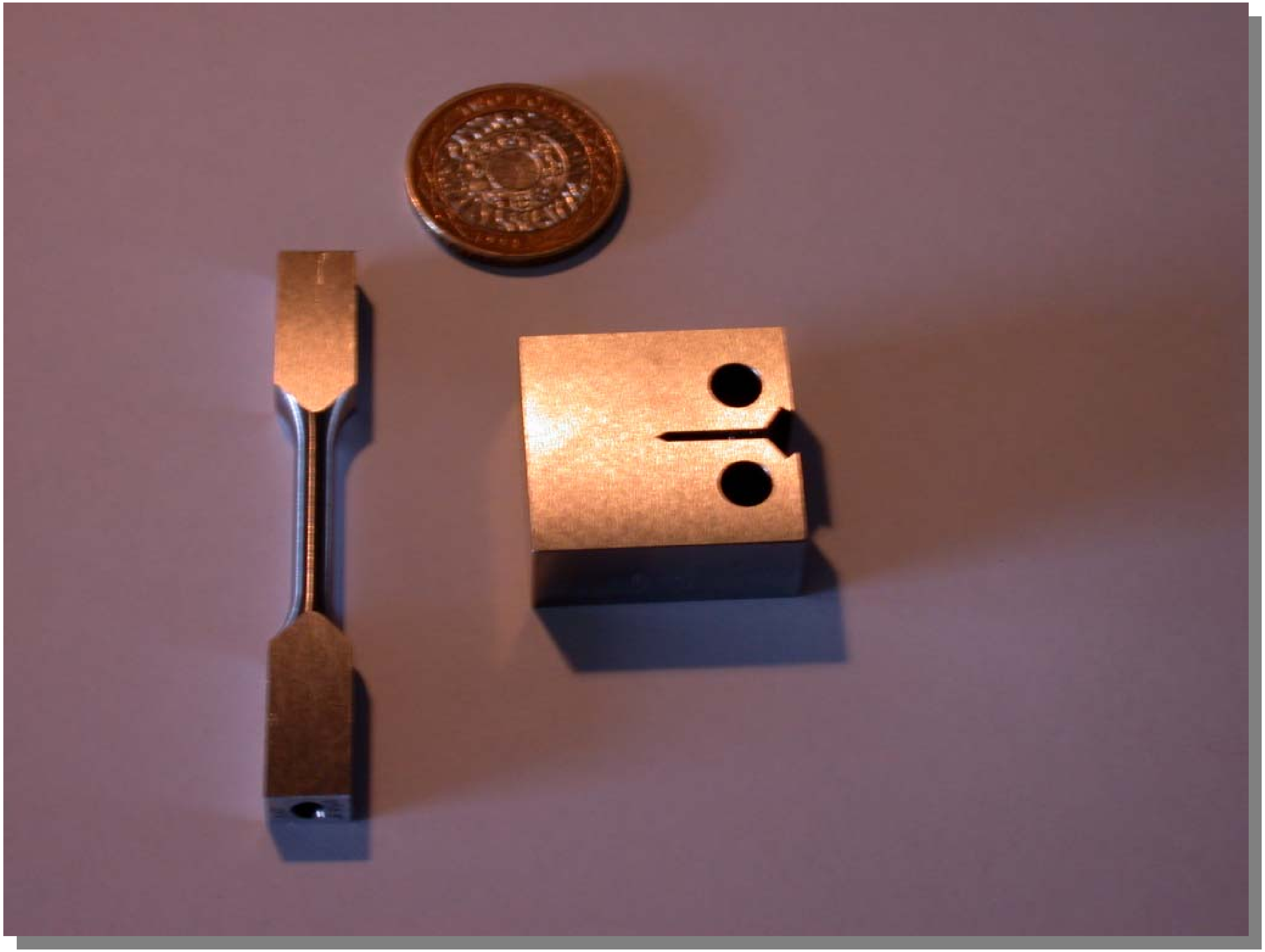
Low temperature transformation: 0.25 T/T_m

Fine microstructure: 40 nm thick plates

Carbide-free

Designed using theory alone

Typical mechanical properties:



2300 MPa, 27 MPa $\mathrm{m}^{\frac{1}{2}}$