

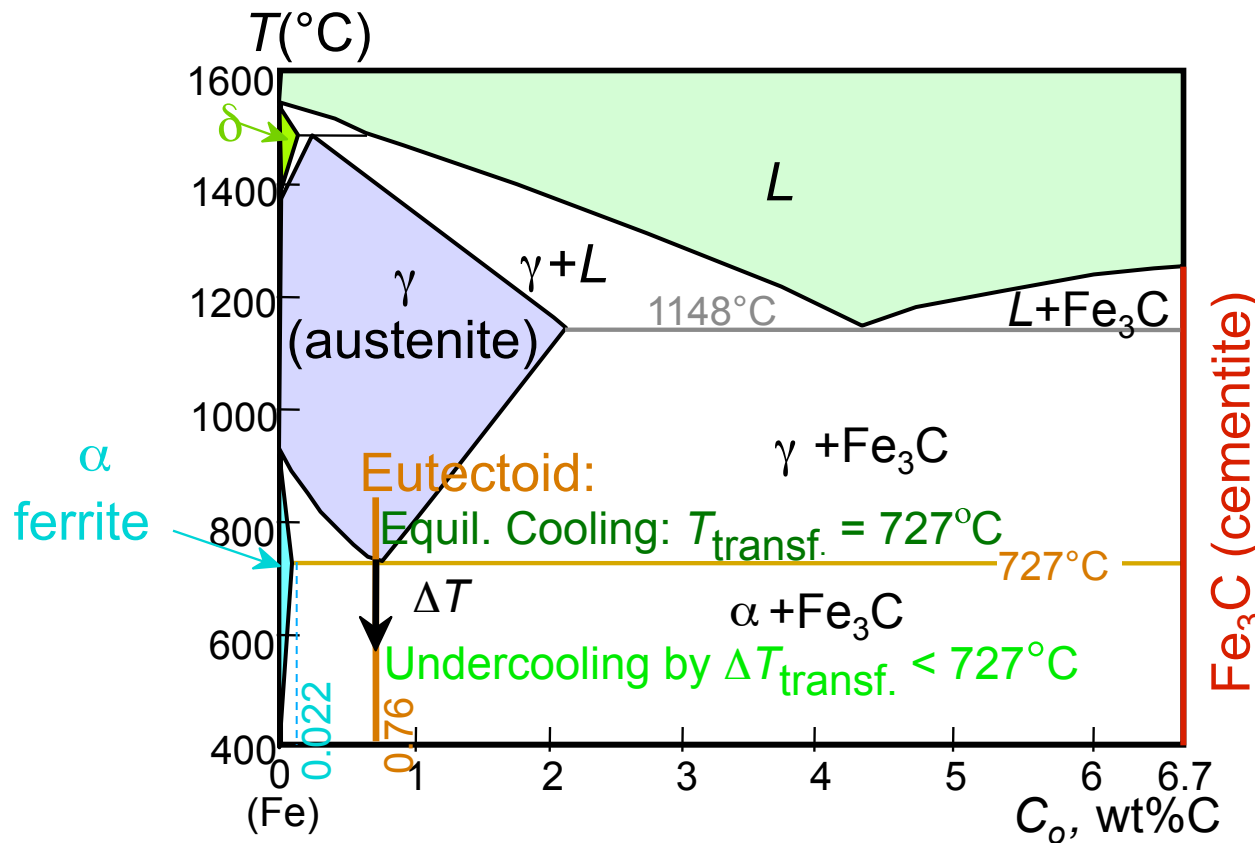
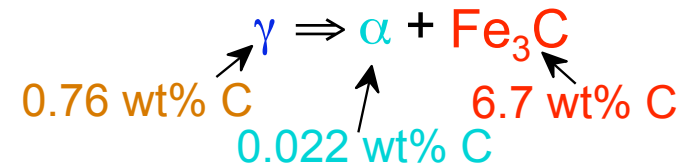
Transformations and undercooling

- Eutectoid transformation (Fe-C System):

- Can make it occur at:

...727°C (cool it slowly)

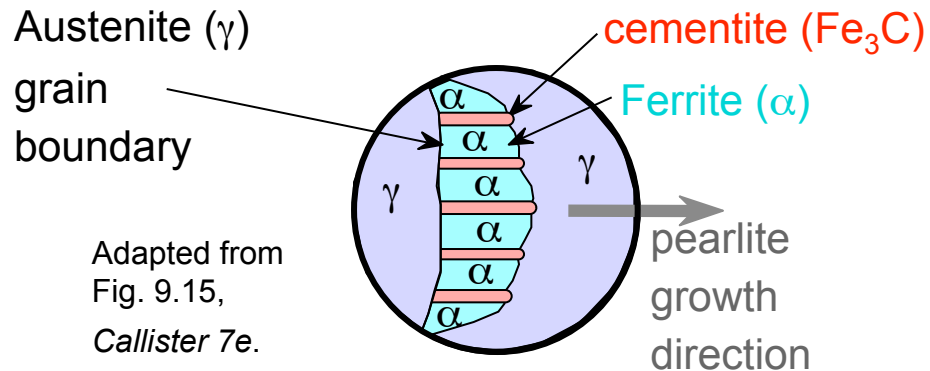
...below 727°C (“undercool” it)



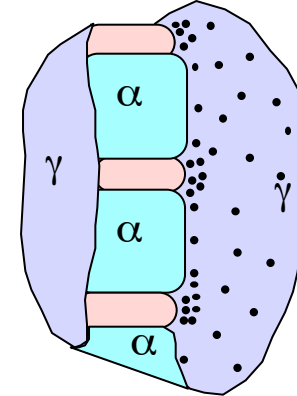
Adapted from Fig. 9.24, Callister 7e. (Fig. 9.24 adapted from *Binary Alloy Phase Diagrams*, 2nd ed., Vol. 1, T.B. Massalski (Ed.-in-Chief), ASM International, Materials Park, OH, 1990.)

Eutectoid transformation rate

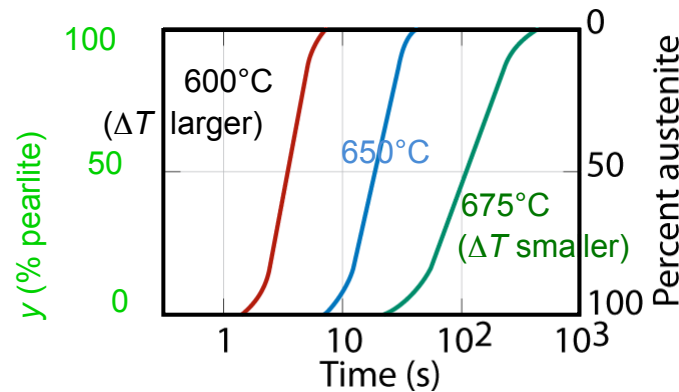
- Growth of pearlite from austenite:



Diffusive flow of C needed



- Recrystallization rate increases with ΔT .

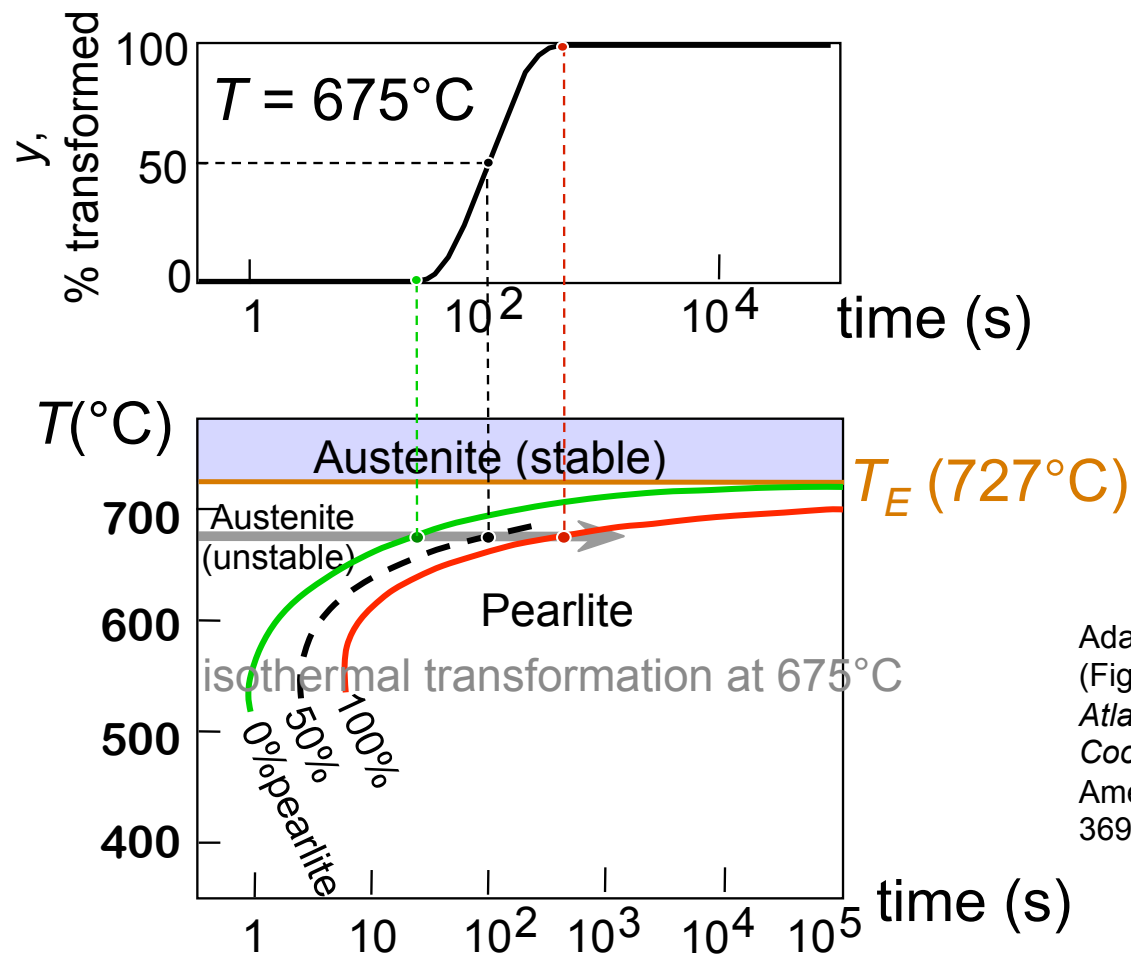


Adapted from Fig. 10.12, Callister 7e.

Course pearlite → formed at higher T - softer
Fine pearlite → formed at low T - harder

Isothermal transformation diagrams

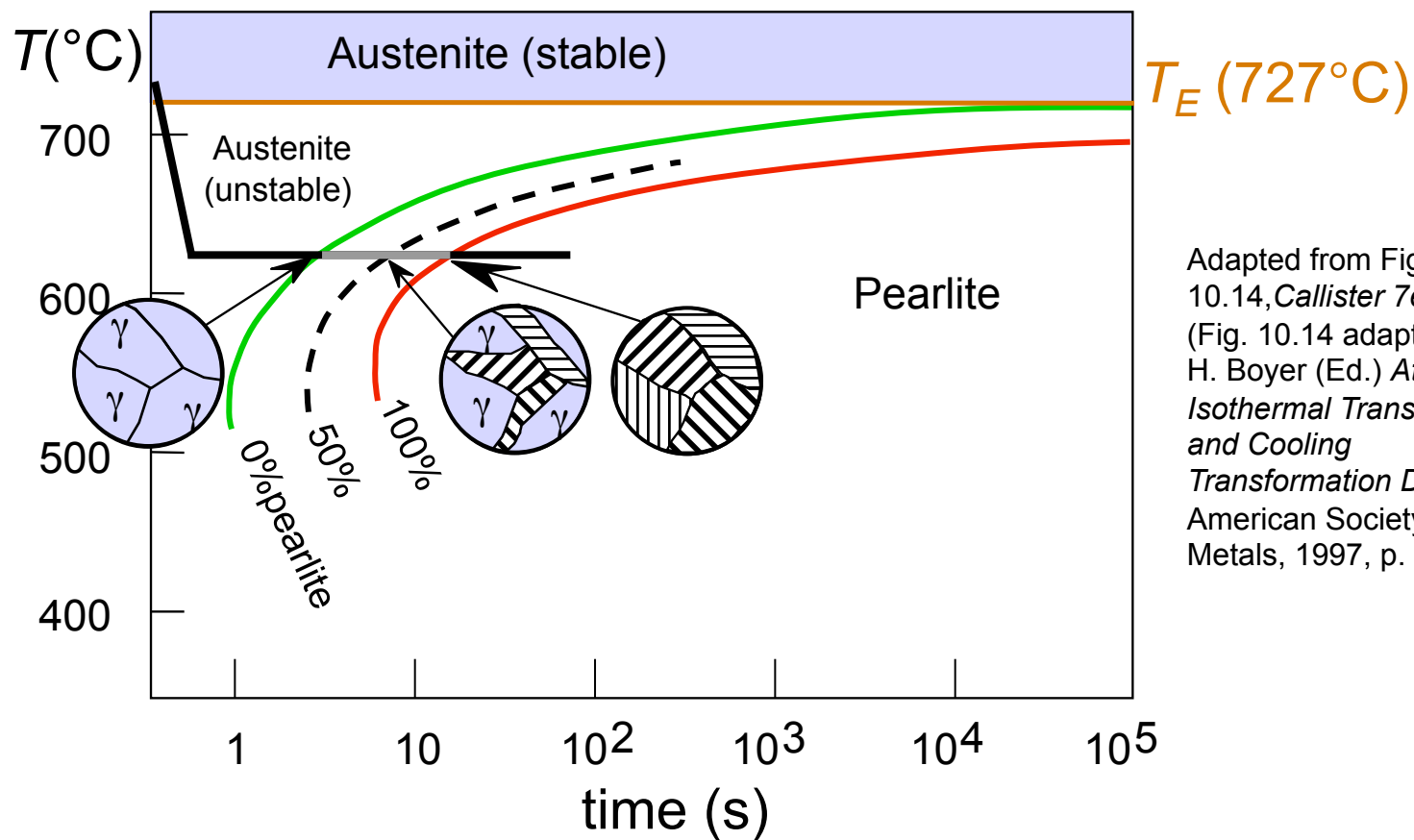
- Fe-C system, $C_o = 0.76 \text{ wt\% C}$
- Transformation at $T = 675^\circ\text{C}$.



Adapted from Fig. 10.13, Callister 7e.
(Fig. 10.13 adapted from H. Boyer (Ed.)
*Atlas of Isothermal Transformation and
Cooling Transformation Diagrams*,
American Society for Metals, 1977, p.
369.)

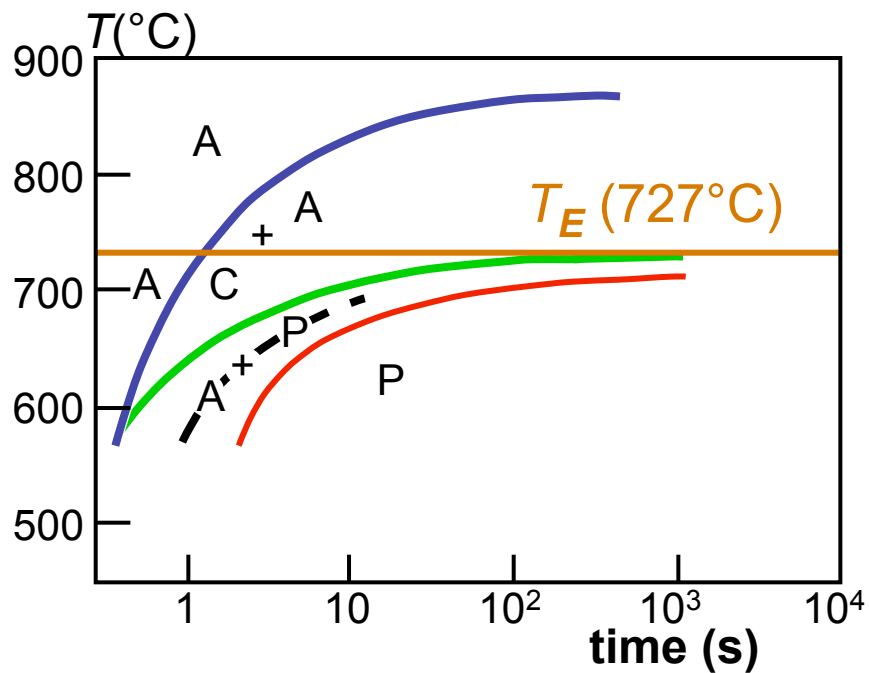
Effect of cooling history

- Eutectoid composition, $C_o = 0.76 \text{ wt\% C}$
- Begin at $T > 727^\circ\text{C}$
- Rapidly cool to 625°C and hold isothermally.

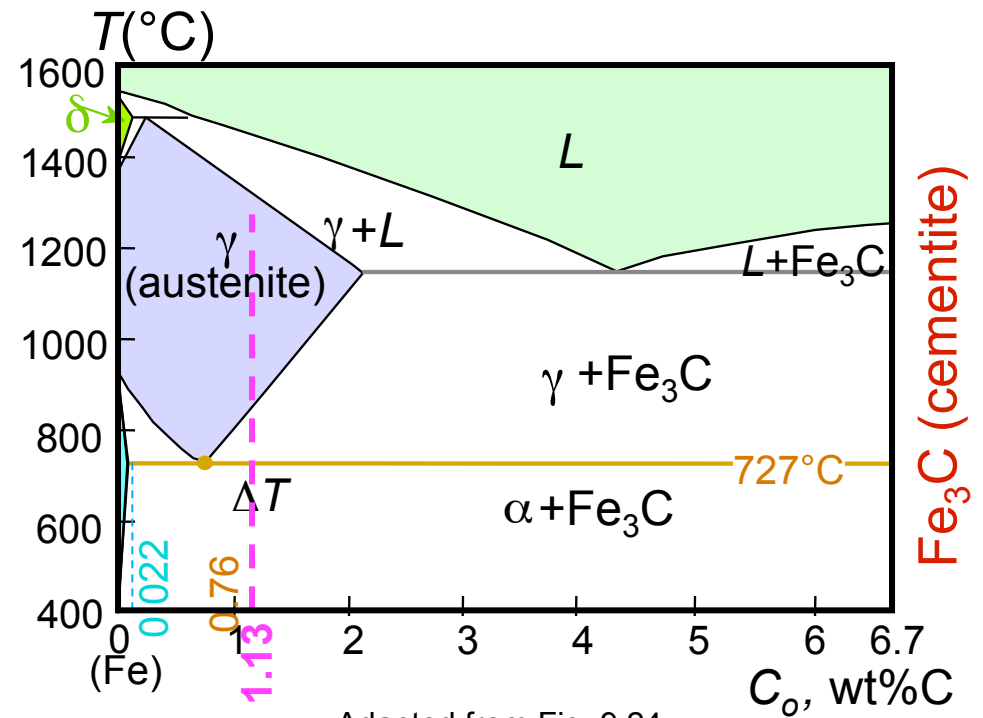


Transformations with proeutectoid materials

$C_o = 1.13 \text{ wt\% C}$



Adapted from Fig. 10.16,
Callister 7e.

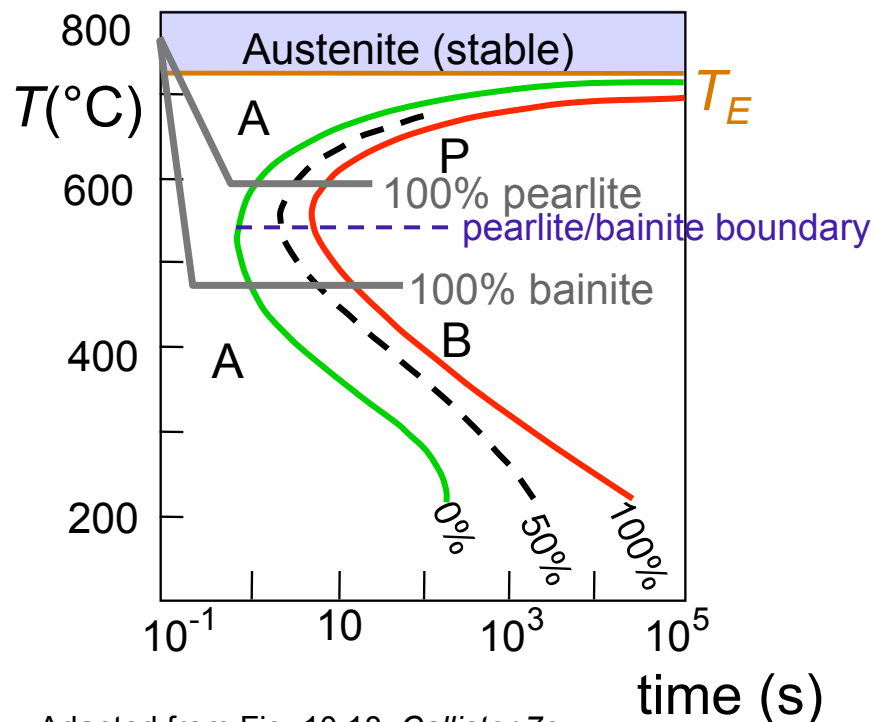


Adapted from Fig. 9.24,
Callister 7e.

Hypereutectoid composition – proeutectoid cementite

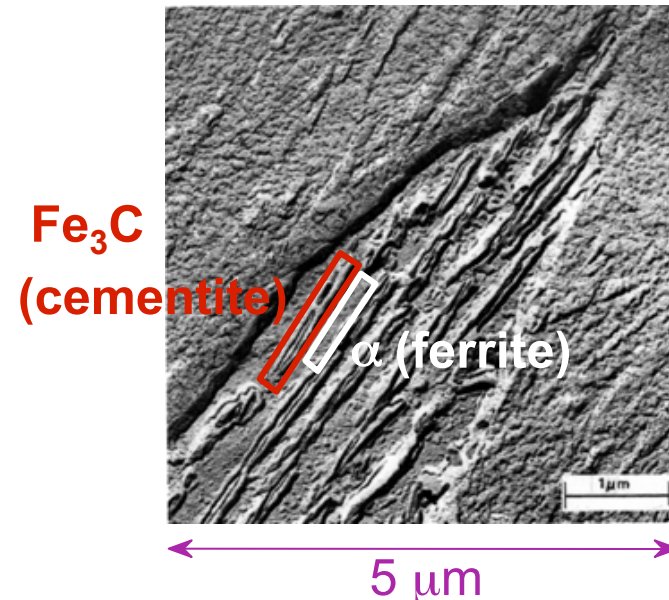
Nonequilibrium transformation products

- Bainite:
 - α lathes (strips) with long rods of Fe_3C
 - diffusion controlled.
- Isothermal Transf. Diagram



Adapted from Fig. 10.18, Callister 7e.

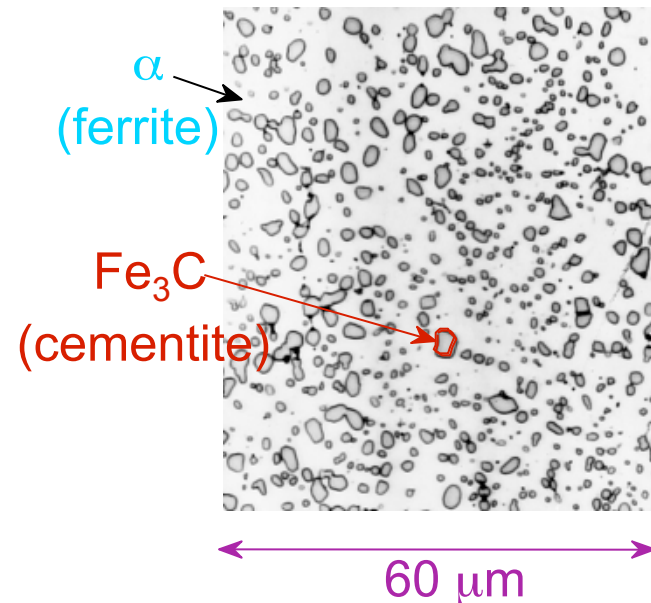
(Fig. 10.18 adapted from H. Boyer (Ed.) *Atlas of Isothermal Transformation and Cooling Transformation Diagrams*, American Society for Metals, 1997, p. 28.)



(Adapted from Fig. 10.17, Callister, 7e. (Fig. 10.17 from *Metals Handbook*, 8th ed., Vol. 8, *Metallography, Structures, and Phase Diagrams*, American Society for Metals, Materials Park, OH, 1973.)

Spheroidite

- Spheroidite:
 - α grains with spherical Fe_3C
 - diffusion dependent.
 - heat bainite or pearlite for long times
 - reduces interfacial area (driving force)

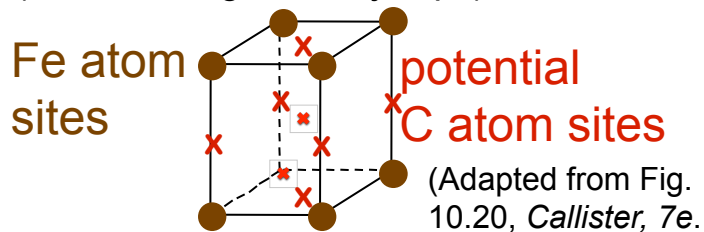


(Adapted from Fig. 10.19, *Callister, 7e*.
(Fig. 10.19 copyright United States
Steel Corporation, 1971.)

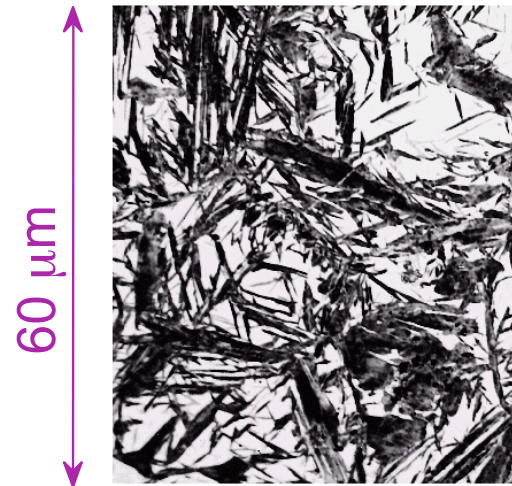
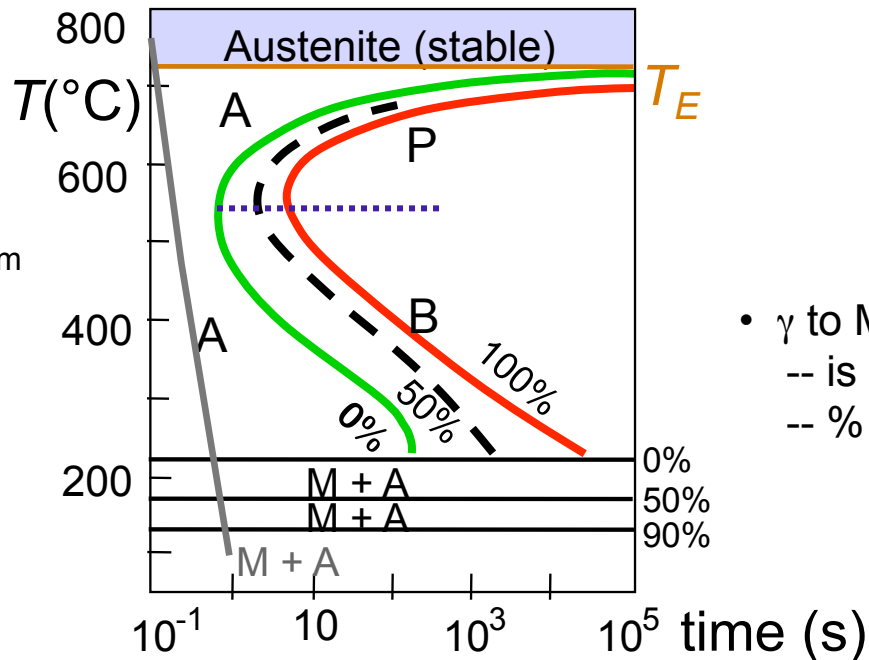
Martensite

- **Martensite:**
-- γ (FCC) to Martensite (BCT)

(involves single atom jumps)



- Isothermal Transf. Diagram



Martensite needles

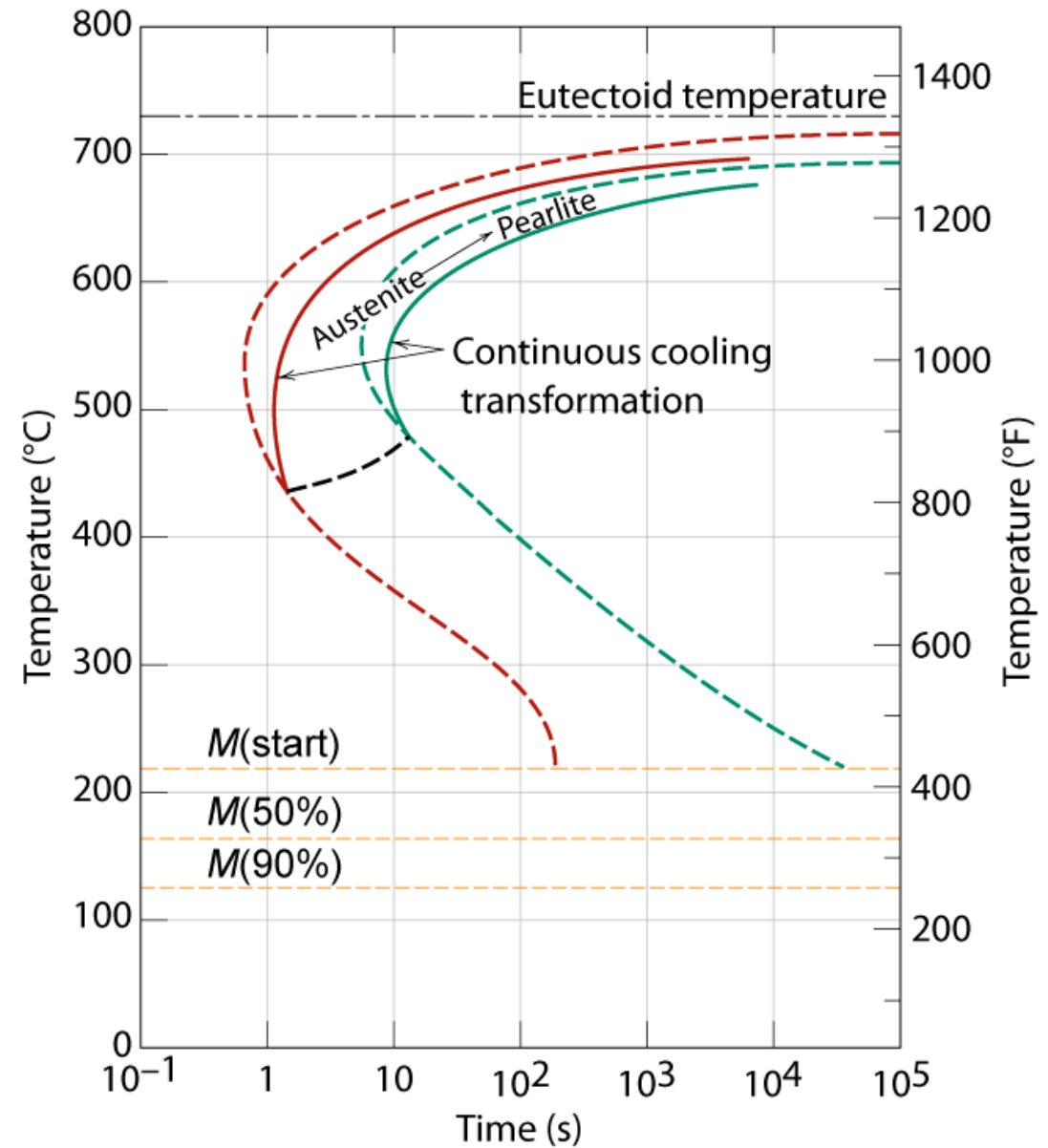
Austenite

(Adapted from Fig. 10.21, Callister, 7e.
(Fig. 10.21 courtesy United States Steel Corporation.)

- γ to M transformation..
-- is rapid
-- % transf. depends on T only.

Cooling curve

plot temp vs. time

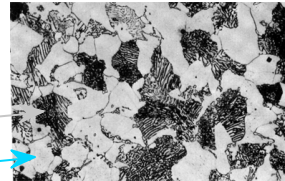


Adapted from
Fig. 10.25,
Callister 7e.

Mechanical properties 1

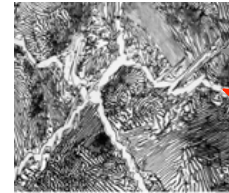
- Effect of wt% C

Pearlite (med)
ferrite (soft)



$C_o < 0.76 \text{ wt\% C}$
Hypoeutectoid

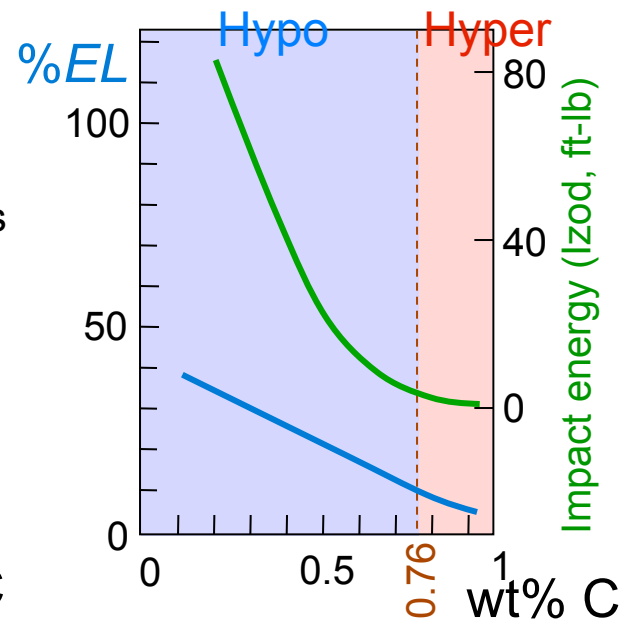
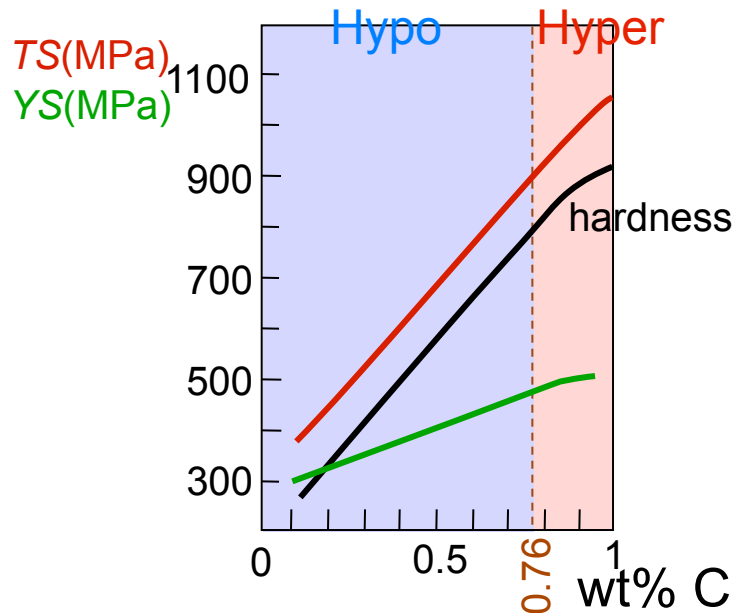
Adapted from Fig. 9.30, Callister 7e. (Fig. 9.30 courtesy Republic Steel Corporation.)



Pearlite (med)
Cementite (hard)

$C_o > 0.76 \text{ wt\% C}$
Hypereutectoid

Adapted from Fig. 9.33, Callister 7e. (Fig. 9.33 copyright 1971 by United States Steel Corporation.)

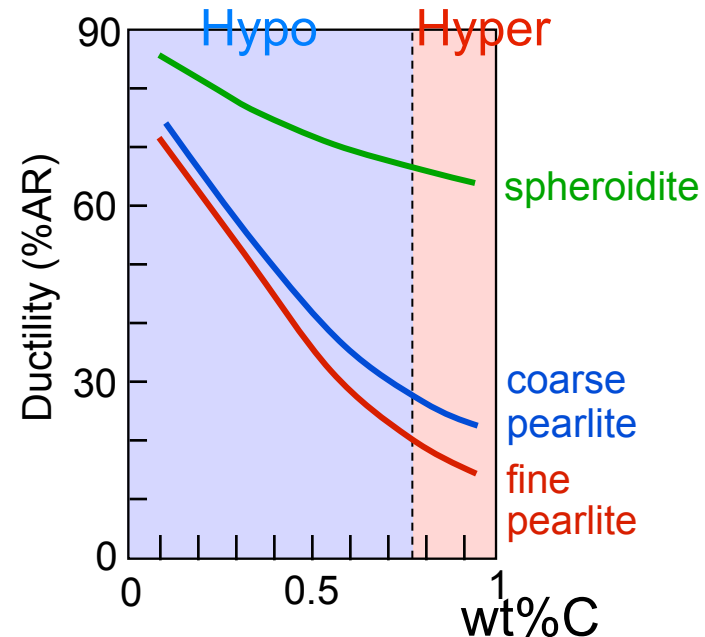
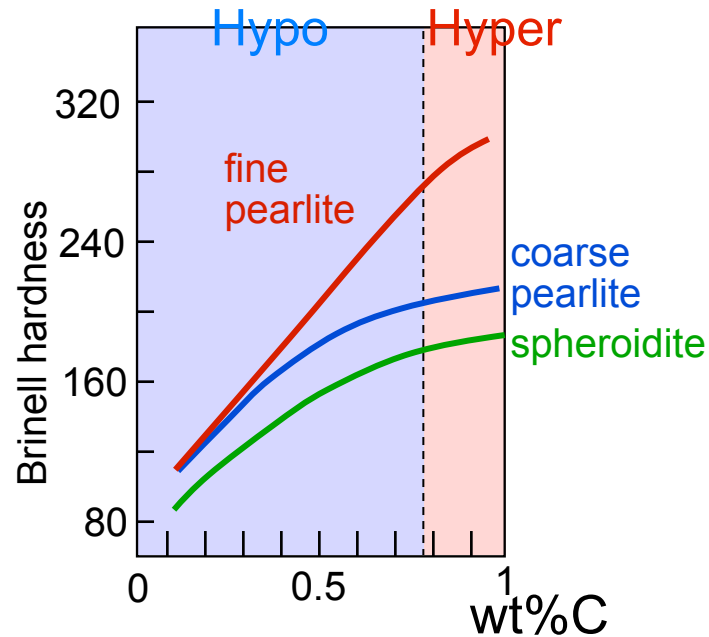


Adapted from Fig. 10.29, Callister 7e. (Fig. 10.29 based on data from *Metals Handbook: Heat Treating*, Vol. 4, 9th ed., V. Masseria (Managing Ed.), American Society for Metals, 1981, p. 9.)

- More wt% C: TS and YS increase, %EL decreases.

Mechanical properties 2

- Fine vs coarse pearlite vs spheroidite

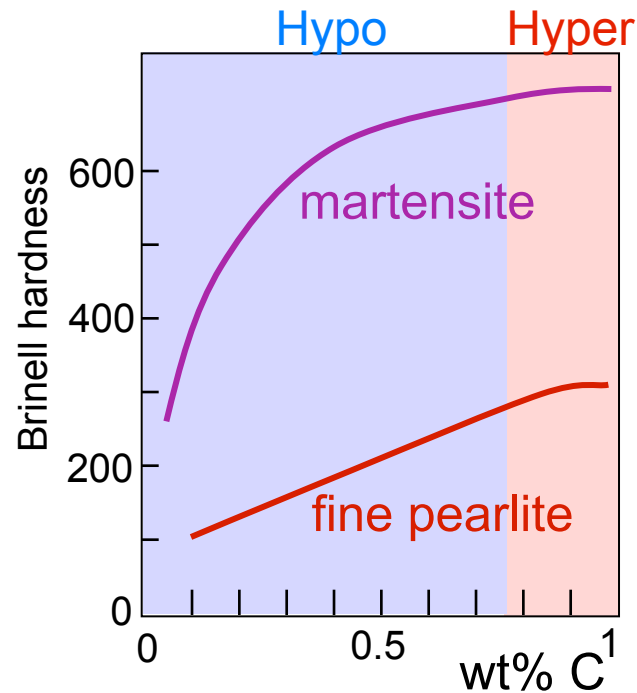


- Hardness: fine > coarse > spheroidite
- %RA: fine < coarse < spheroidite

Adapted from Fig. 10.30, *Callister 7e*.
(Fig. 10.30 based on data from *Metals Handbook: Heat Treating*, Vol. 4, 9th ed., V. Masseria (Managing Ed.), American Society for Metals, 1981, pp. 9 and 17.)

Mechanical properties 3

- Fine Pearlite vs Martensite:

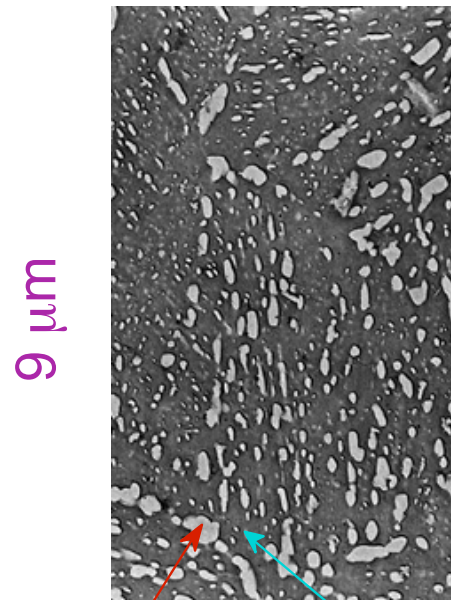
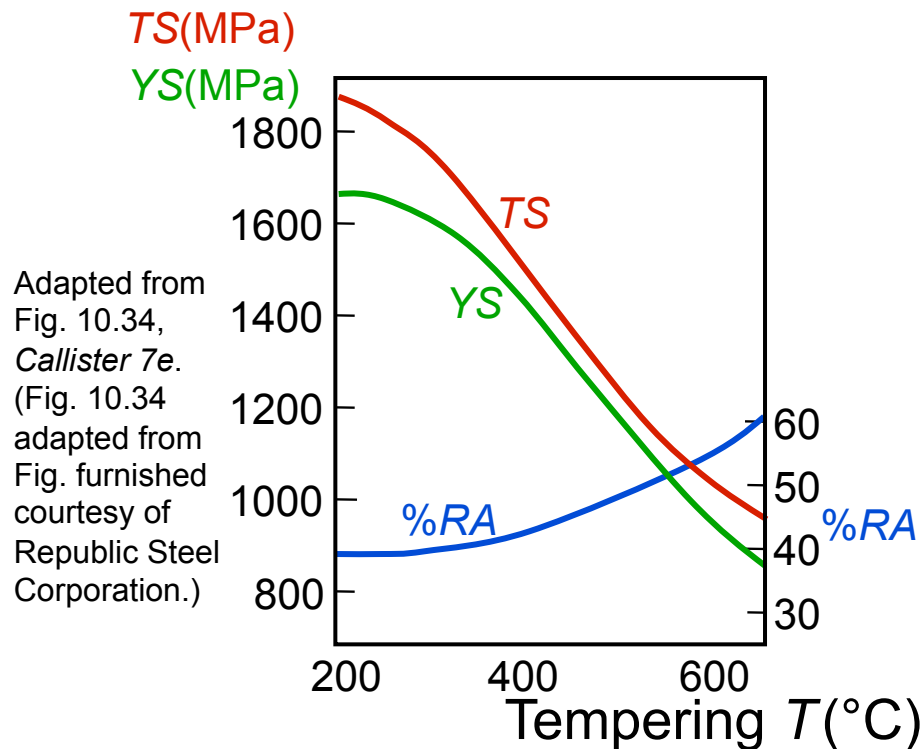


Adapted from Fig. 10.32, *Callister 7e*. (Fig. 10.32 adapted from Edgar C. Bain, *Functions of the Alloying Elements in Steel*, American Society for Metals, 1939, p. 36; and R.A. Grange, C.R. Hribal, and L.F. Porter, *Metall. Trans. A*, Vol. 8A, p. 1776.)

- Hardness: fine pearlite << martensite.

Tempered martensite

- reduces brittleness of martensite,
- reduces internal stress caused by quenching.



Adapted from Fig. 10.33, *Callister 7e*. (Fig. 10.33 copyright by United States Steel Corporation, 1971.)

- produces extremely small Fe_3C particles surrounded by α .
- decreases TS , YS but increases $\%RA$

Summary

