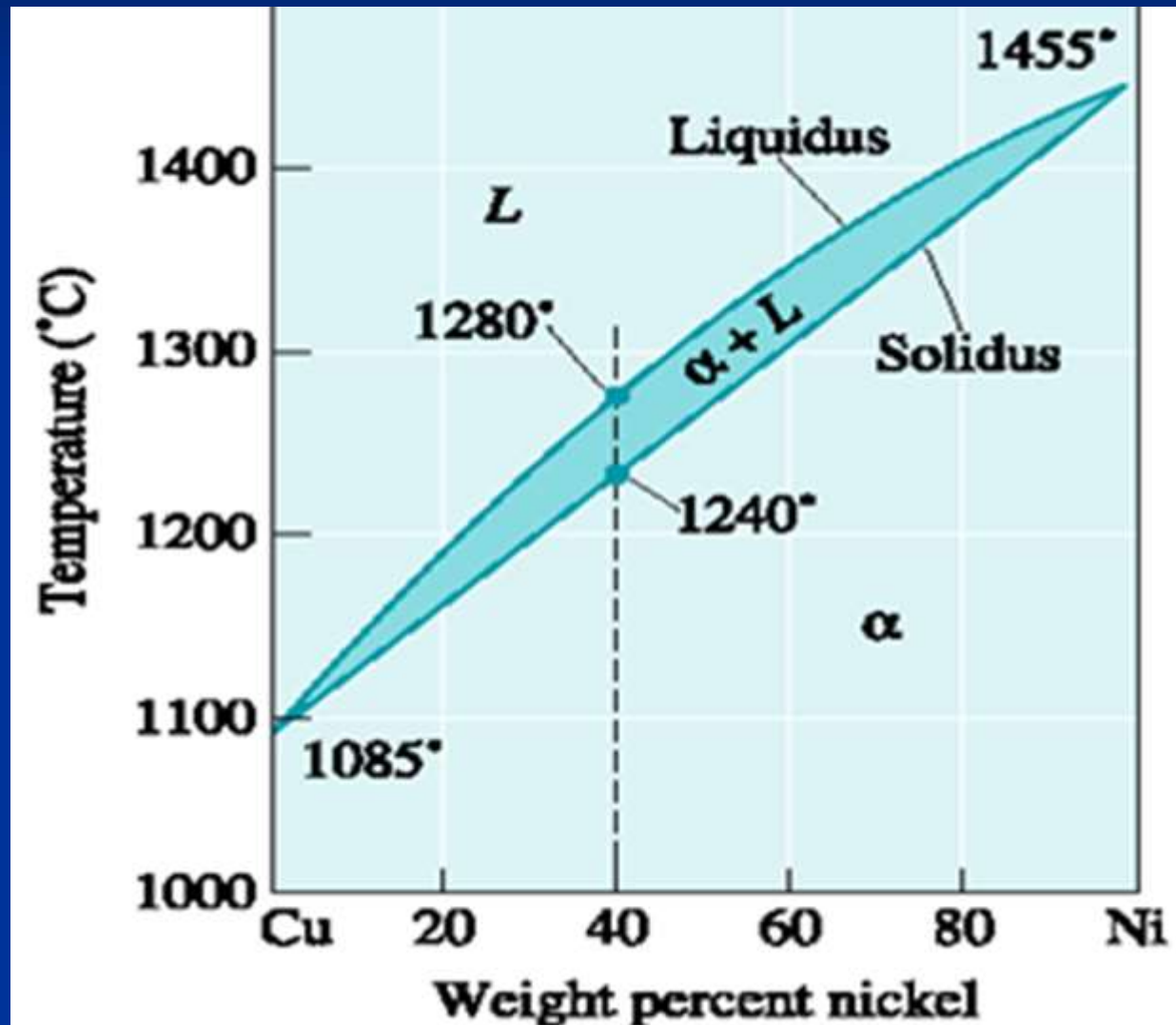


DIAGRAMA DE EQUILÍBRIO FERRO CARBONO

Engenharia e Ciência dos Materiais I

Profa.Dra. Luralice Canale

REVISÃO



REVISÃO

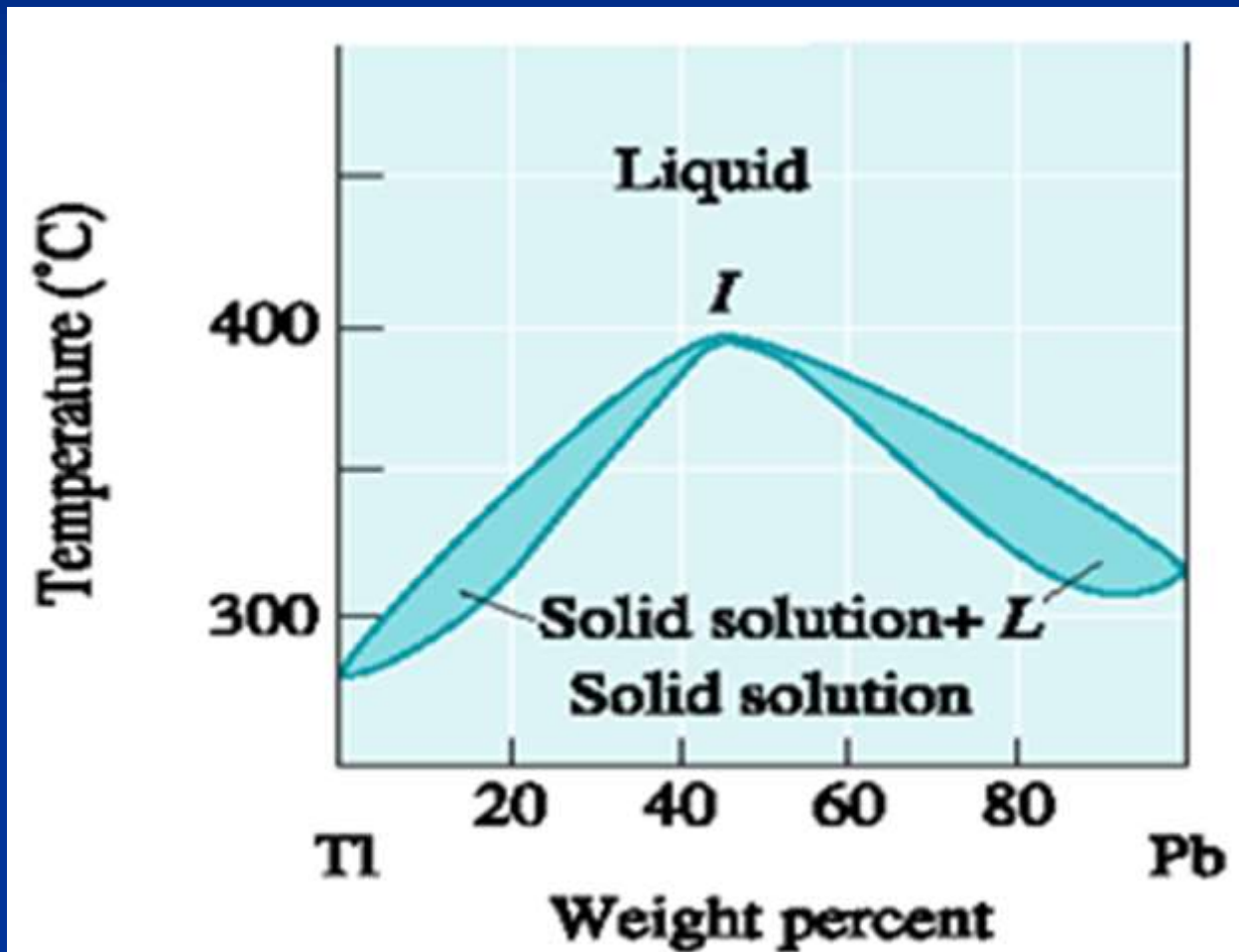
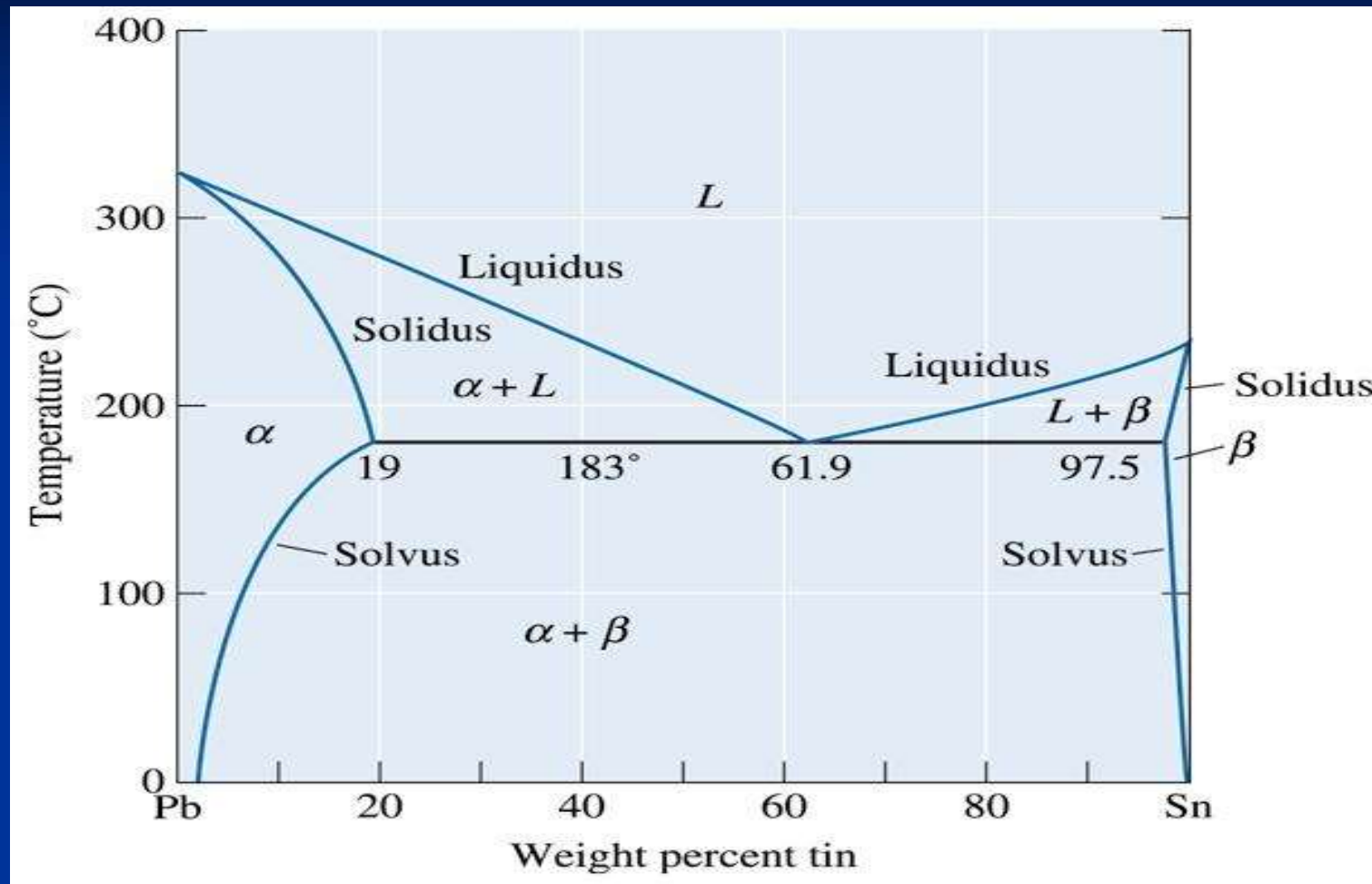


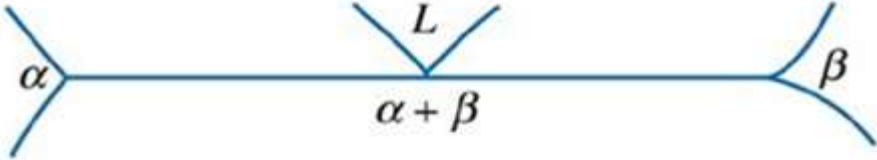
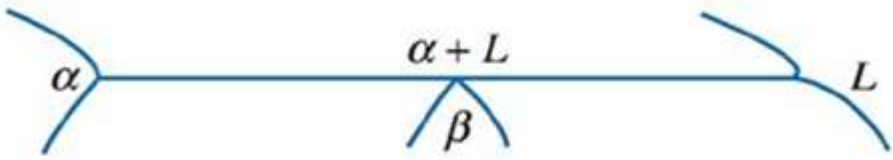
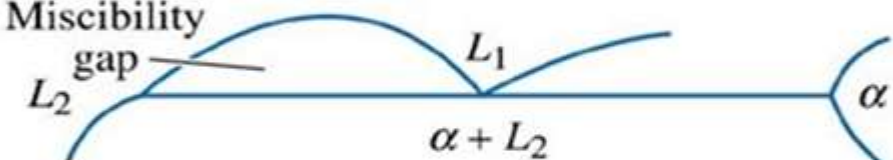
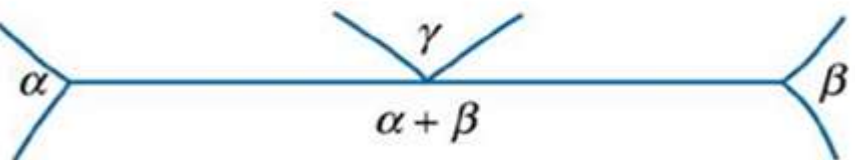
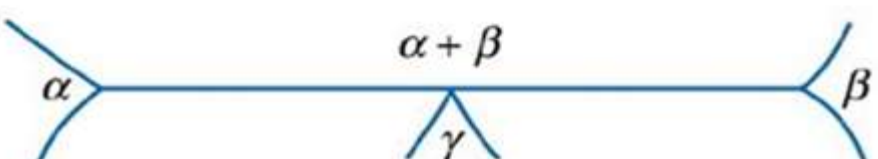
Diagrama de fase eutético

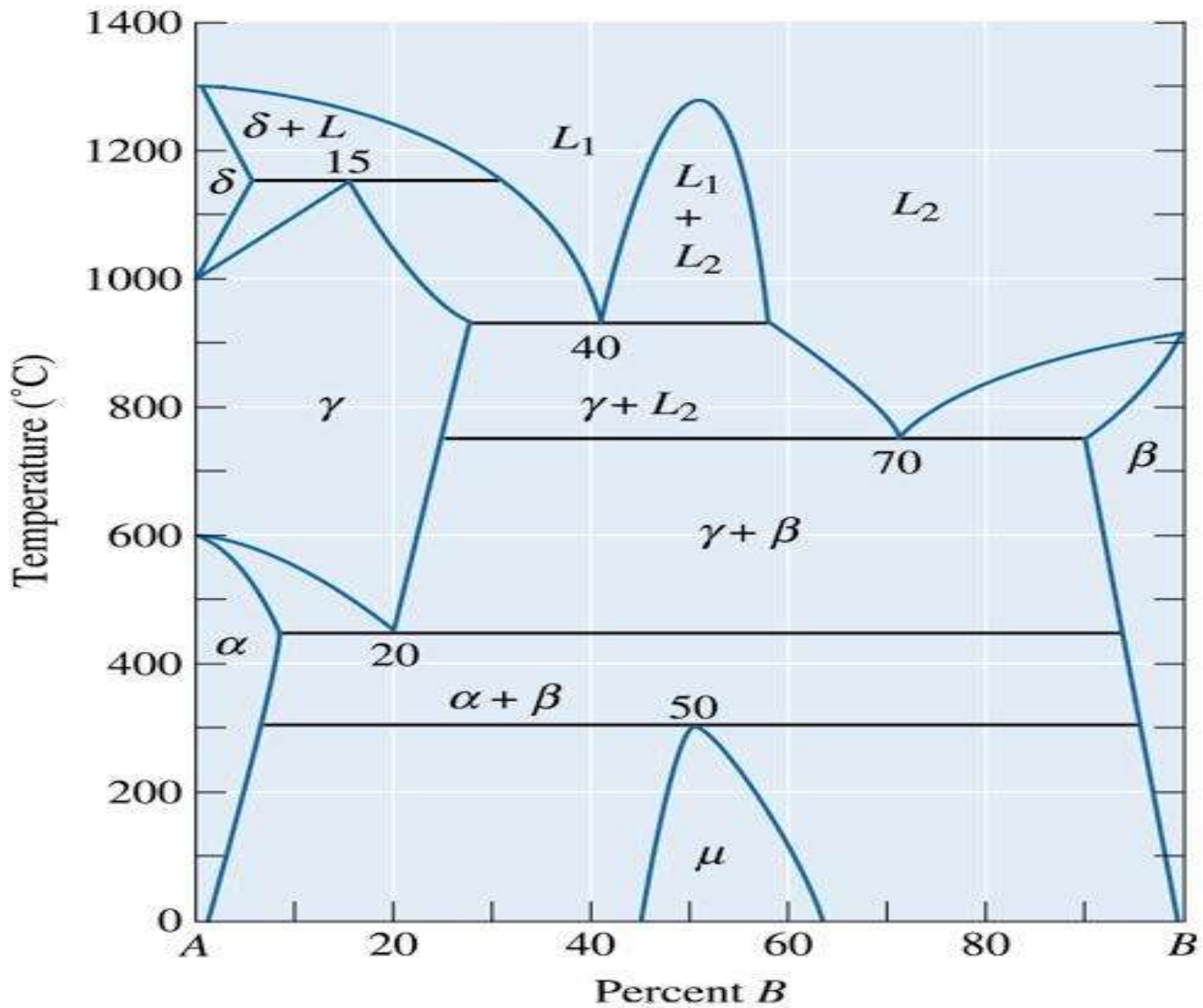


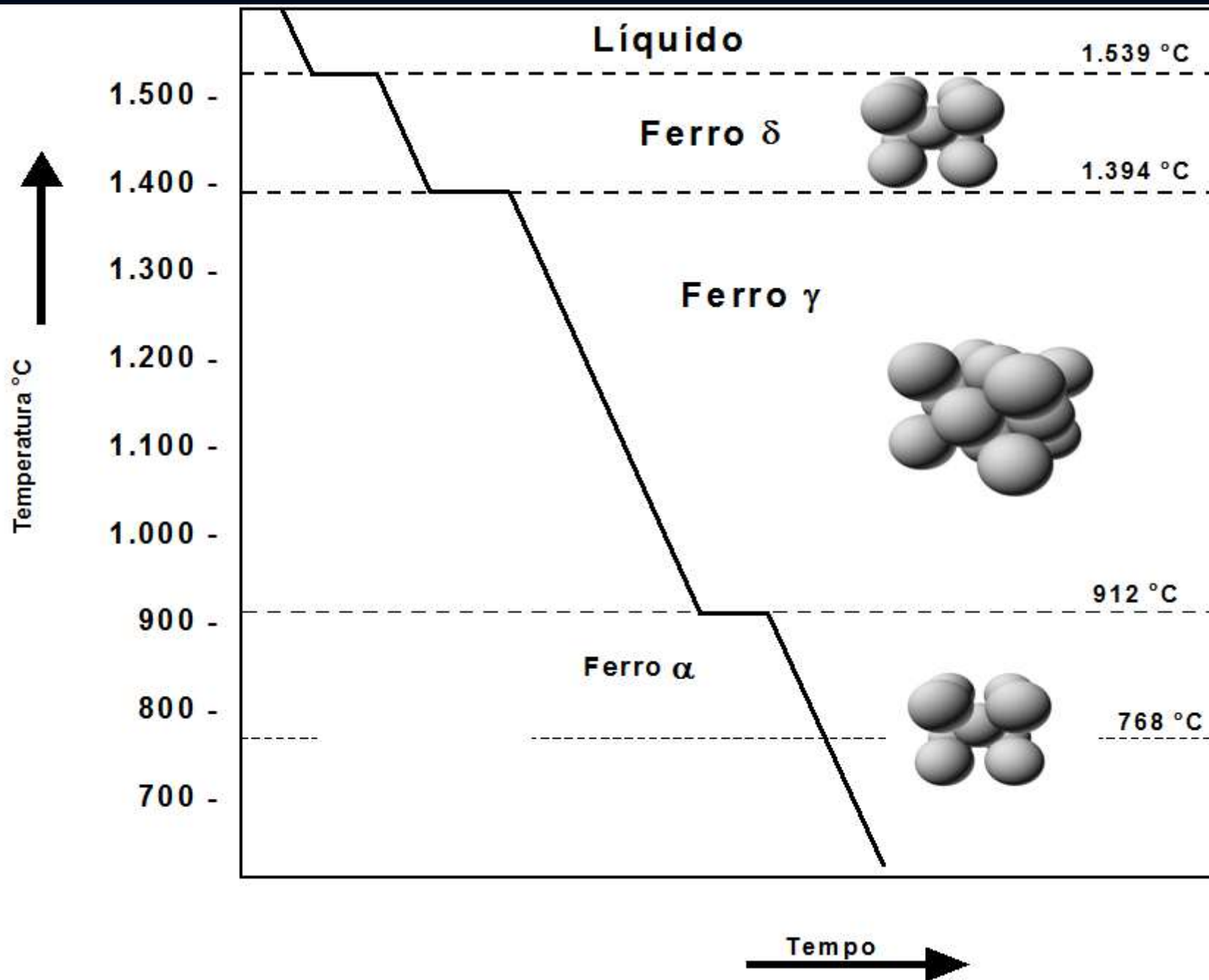
SOLVUS –

Uma curva de solubilidade que separa uma região de uma única fase para uma região de duas fases .

REAÇÕES ENVOLVENDO 3 FASES

EUTÉTICO	$L \rightarrow \alpha + \beta$	
PERITÉTICO	$\alpha + L \rightarrow \beta$	
MONOTÉTICO	$L_1 \rightarrow L_2 + \alpha$	
EUTETÓIDE	$\gamma \rightarrow \alpha + \beta$	
PERITETÓIDE	$\alpha + \beta \rightarrow \gamma$	





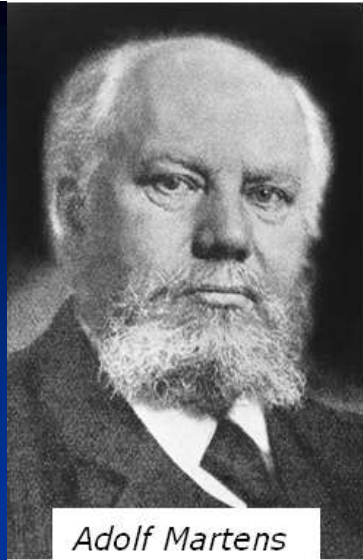
LIGAS FERRO-CARBONO

- De todos os sistemas de ligas binárias, o que é possivelmente o mais importante é aquele formado pelo ferro e o carbono. Tanto os aços como os ferros fundidos, que são os principais materiais estruturais em toda e qualquer cultura tecnologicamente avançada, são essencialmente ligas ferro-carbono.
- As ligas com até 2,0% de carbono são chamadas aços e acima deste teor, ferros fundidos.



Edgar C. Bain

Edgar Bain 1891-1971



Adolf Martens

1850-1914



Sir William Chandler Roberts-Austen (1843-1902).

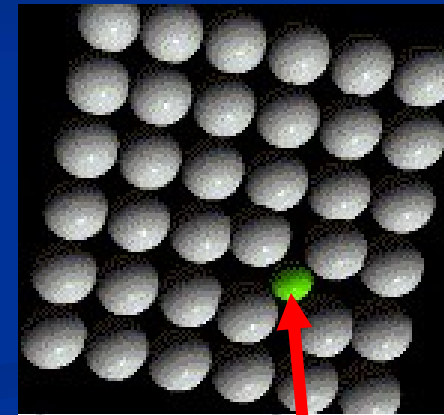


Adolf Ledebur (1837-1916).

- Durante o processo de solidificação dos aços, é possível verificar no aço o aparecimento de microconstituintes como ferrita, cementita, perlita e austenita.

FERRO PURO

- FERRO α = FERRITA
- FERRO γ = AUSTENITA
- FERRO δ = FERRITA δ
- TF= 1534 °C
- As fases α , γ e δ FORMAM soluções sólidas com Carbono intersticial



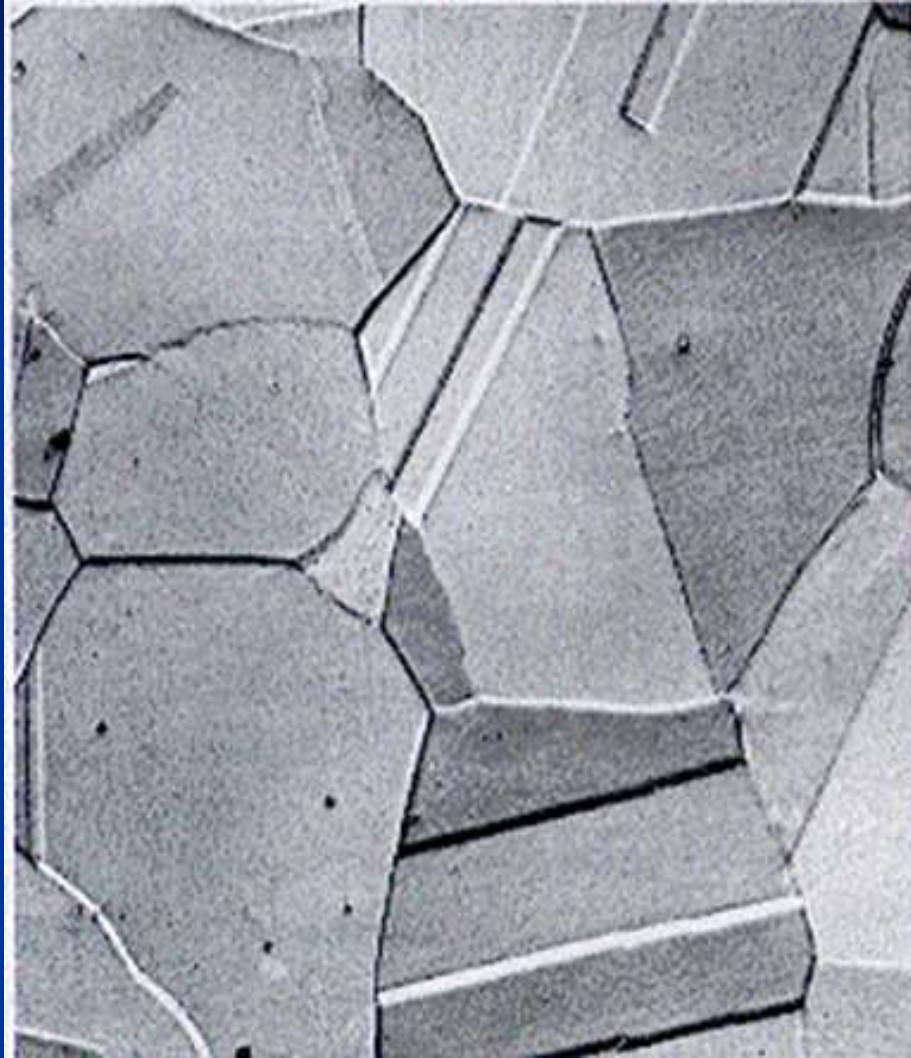
CARBONO



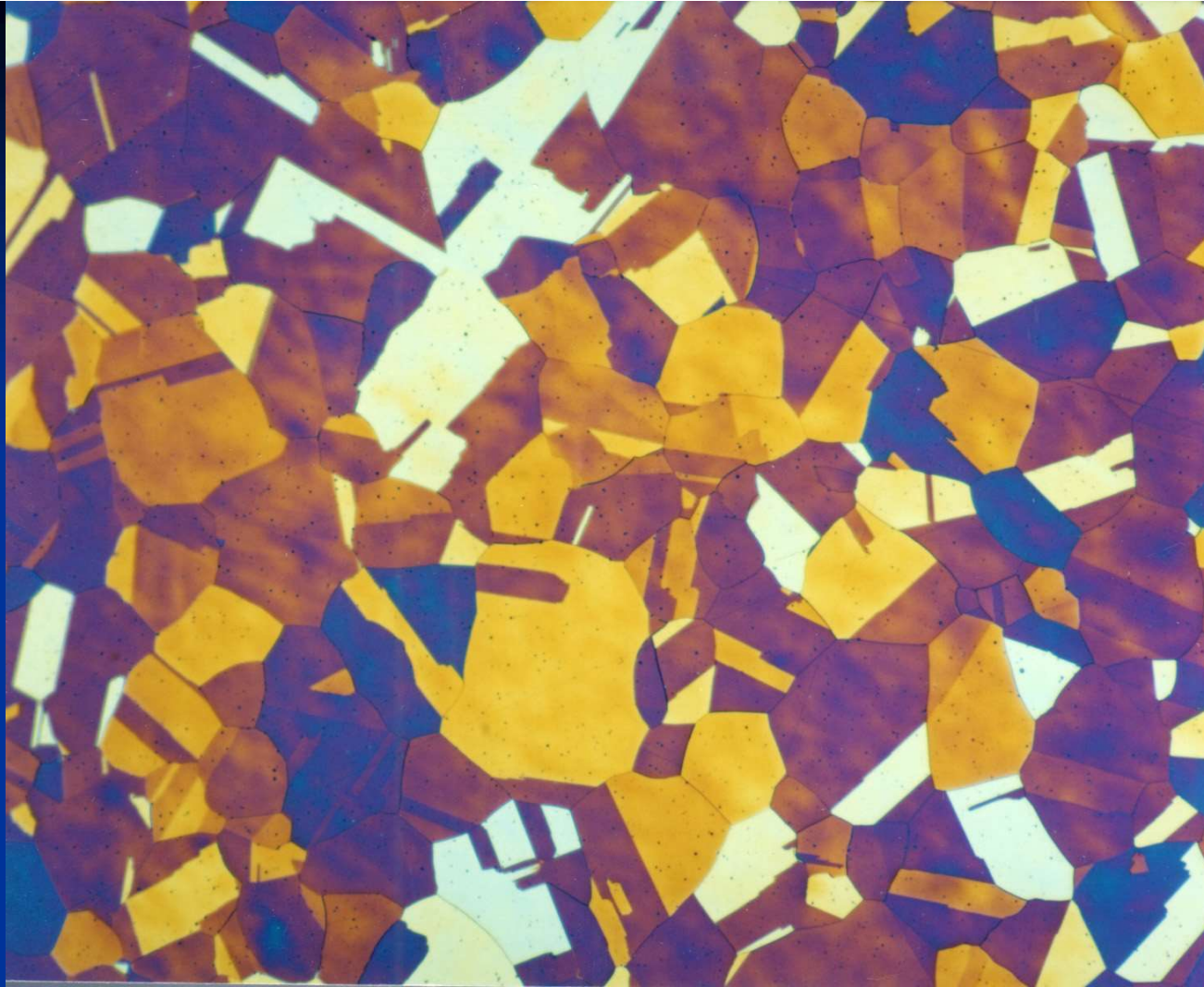
Ferrite grain boundaries in an interstitial-free sheet steel.
Etched with Marshall's Reagent + HF. Original at 200X.



Ferrite grains (in the interior of the lamination sheet steel) revealed using Klemm's I tint etch. Original magnification was 100X. Viewed with polarized light plus sensitive tint.



AUSTENITA



Austenite grains, with annealing twins, in type 316 stainless steel (Fe - $<0.08\%$ C - $<2\%$ Mn - $<1\%$ Si - 17% Cr - 12% Ni - 2.5% Mo) color etched with Beraha's reagent.

CEMENTITA

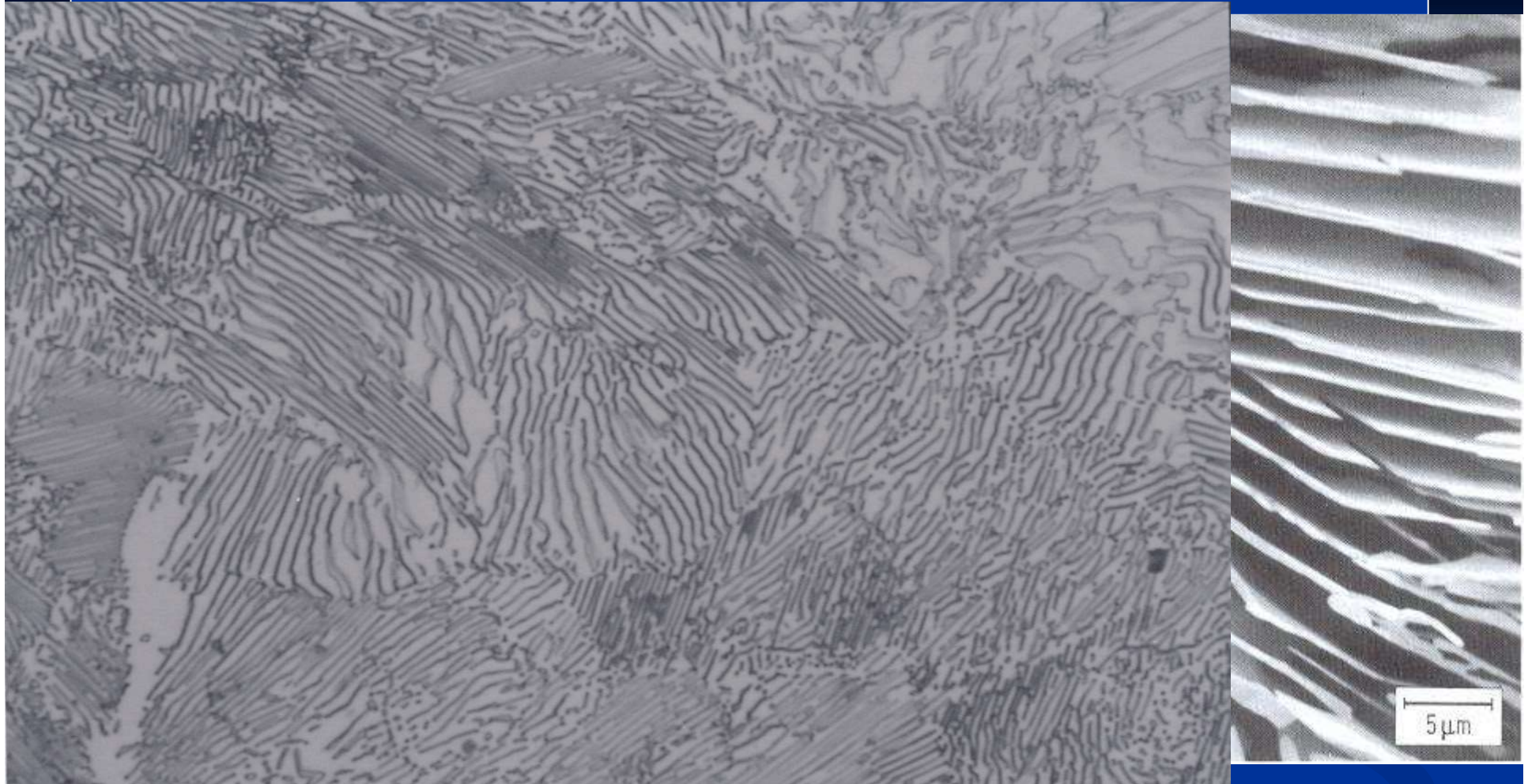
- Forma-se quando o limite de solubilidade do carbono é ultrapassado (6,7% de C)
- É dura e frágil
- Cristaliza no sistema ortorrômbico (com 12 átomos de Fe e 4 de C por célula unitária)



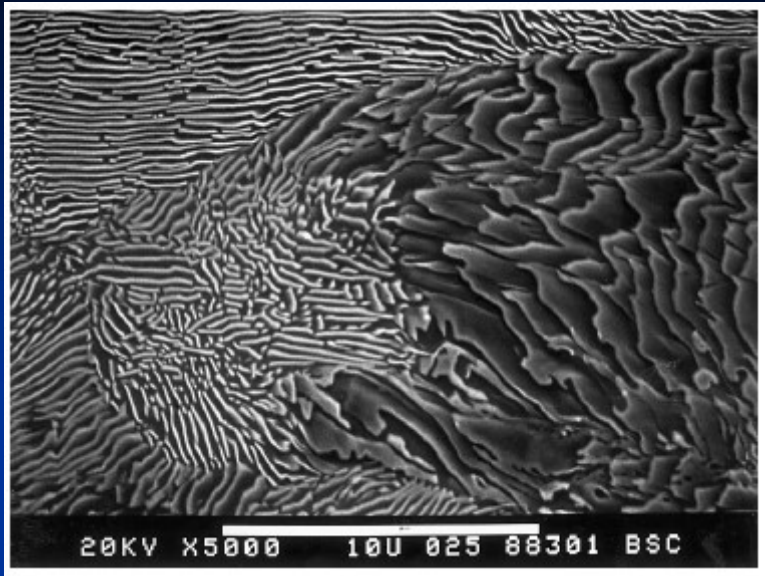
PERLITA

- Essa microestrutura formada nos aços eutetóides abaixo da temperatura do eutetóide composta por camadas alternadas de lamelas de ferrita e cementita é conhecida por perlita, pois quando vista ao microscópio possui uma aparência que lembra madrepérola

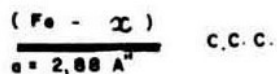
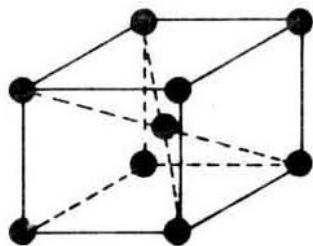
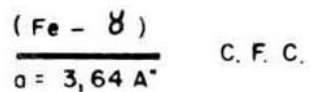
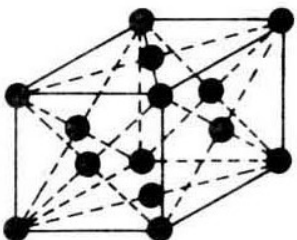
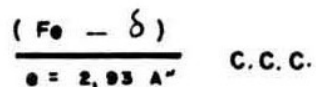
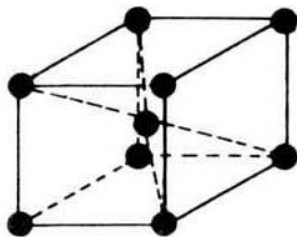
PERLITA



Coarse pearlitic structure in isothermally annealed (780 °C, 1436 °F – 1 h, isothermally transformed) 1080 steel (Fe – 0.8% C – 0.75% Mn) etched with 4% picral. All of the lamellae are resolvable. Original at 1000X.

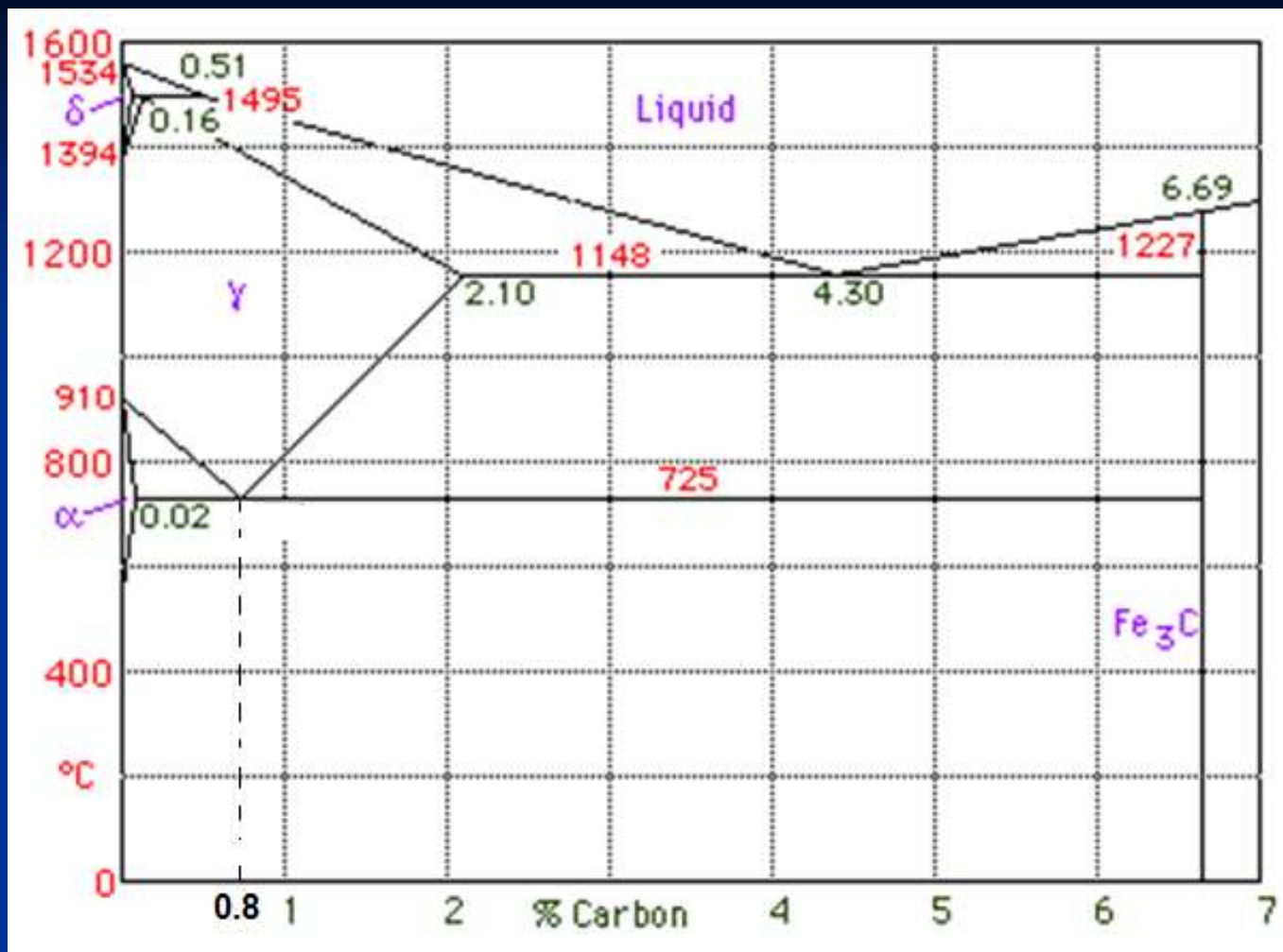


1) - Redes Atômicas



Propriedades Mecânicas

	DUREZA (HB)	R. TRAÇÃO	ALONGAM.
FERRITA	80	30 kgf/mm ²	40%
PERLITA	200	85 " "	10%
CEMENTITA	800	100 " "	0%



AÇO

**FERRO
FUNDIDO**



EXTRA OFERTA

MESA DE FERRO FUDIDO

5

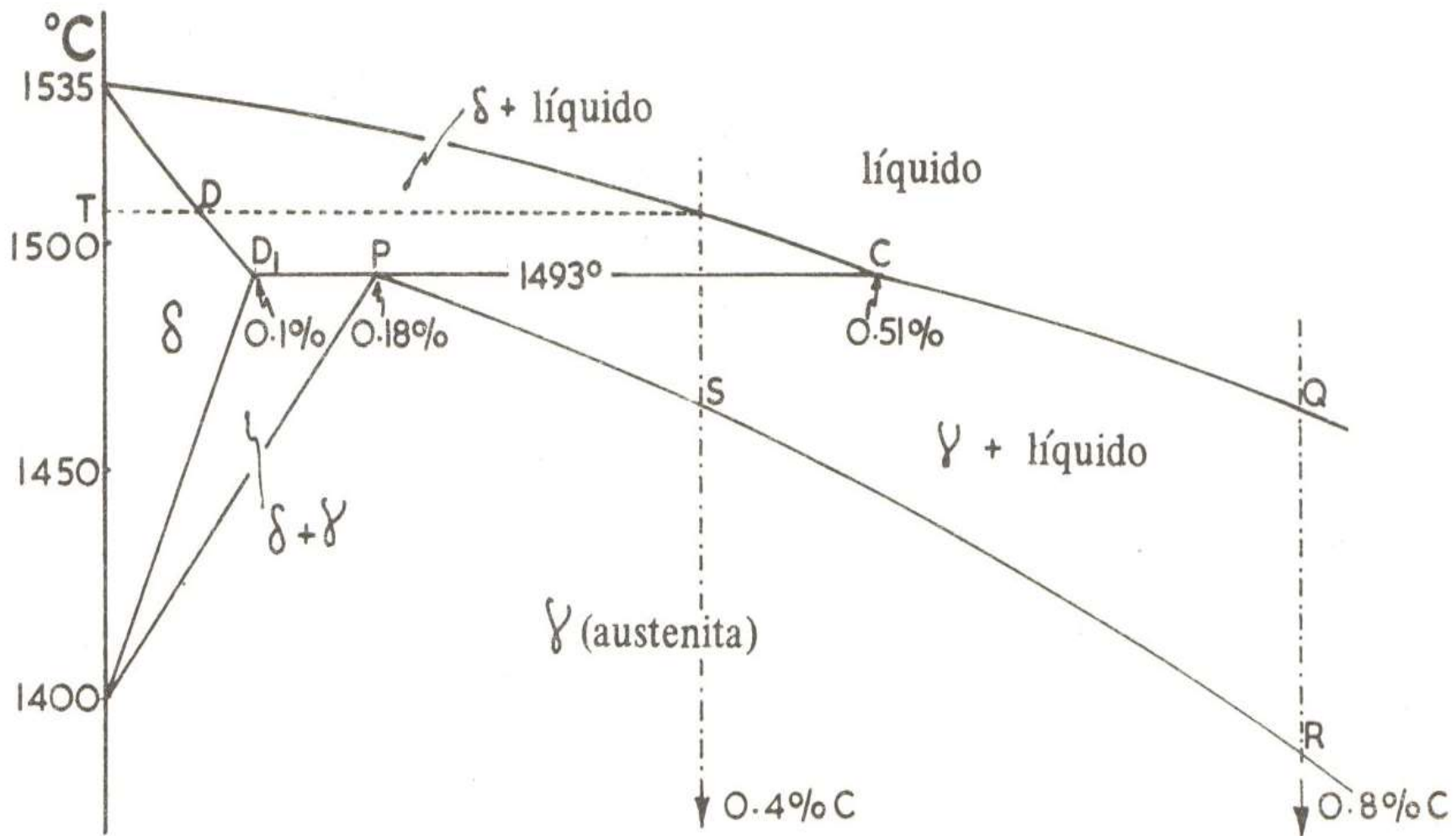
x

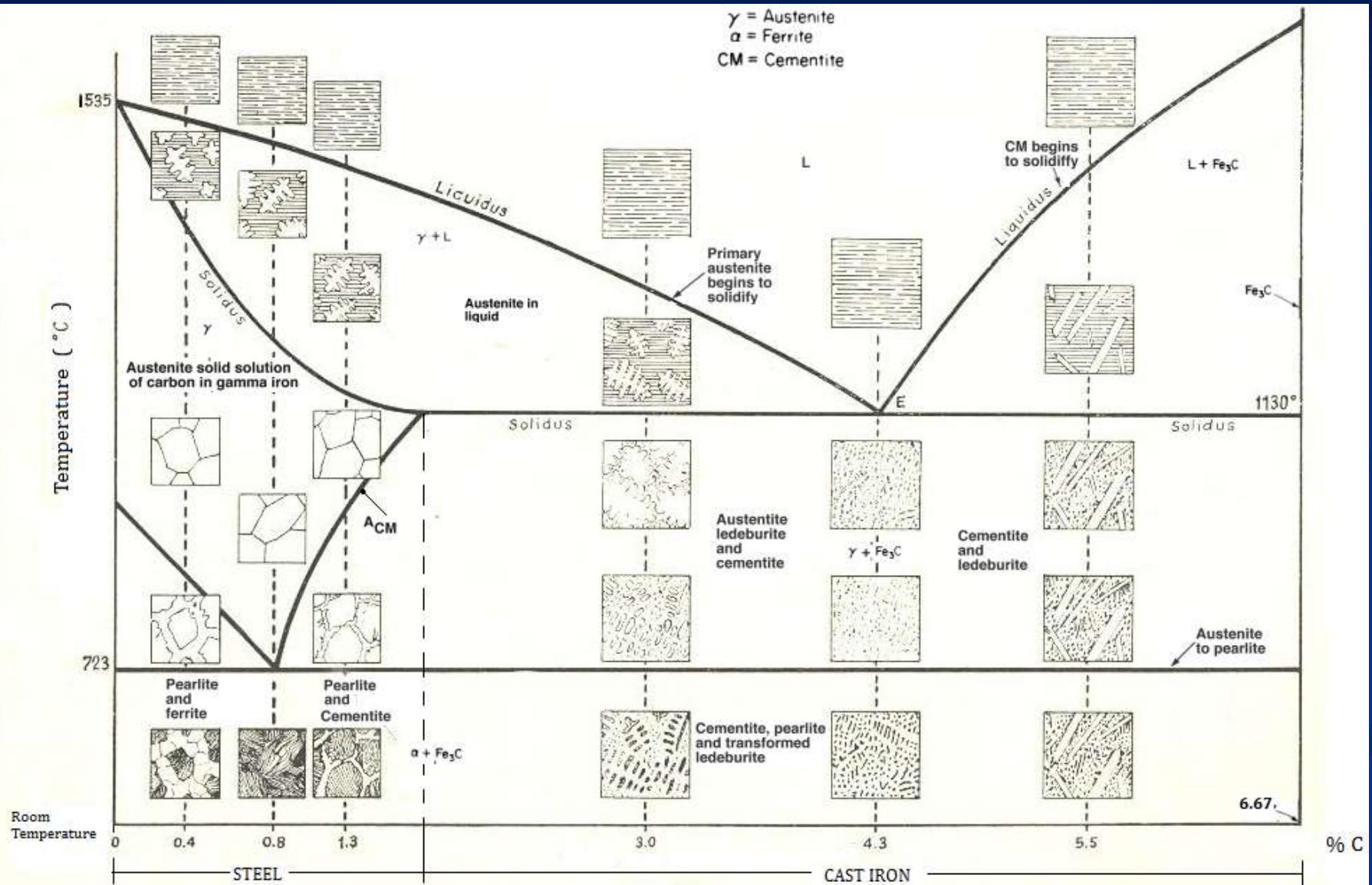
3180

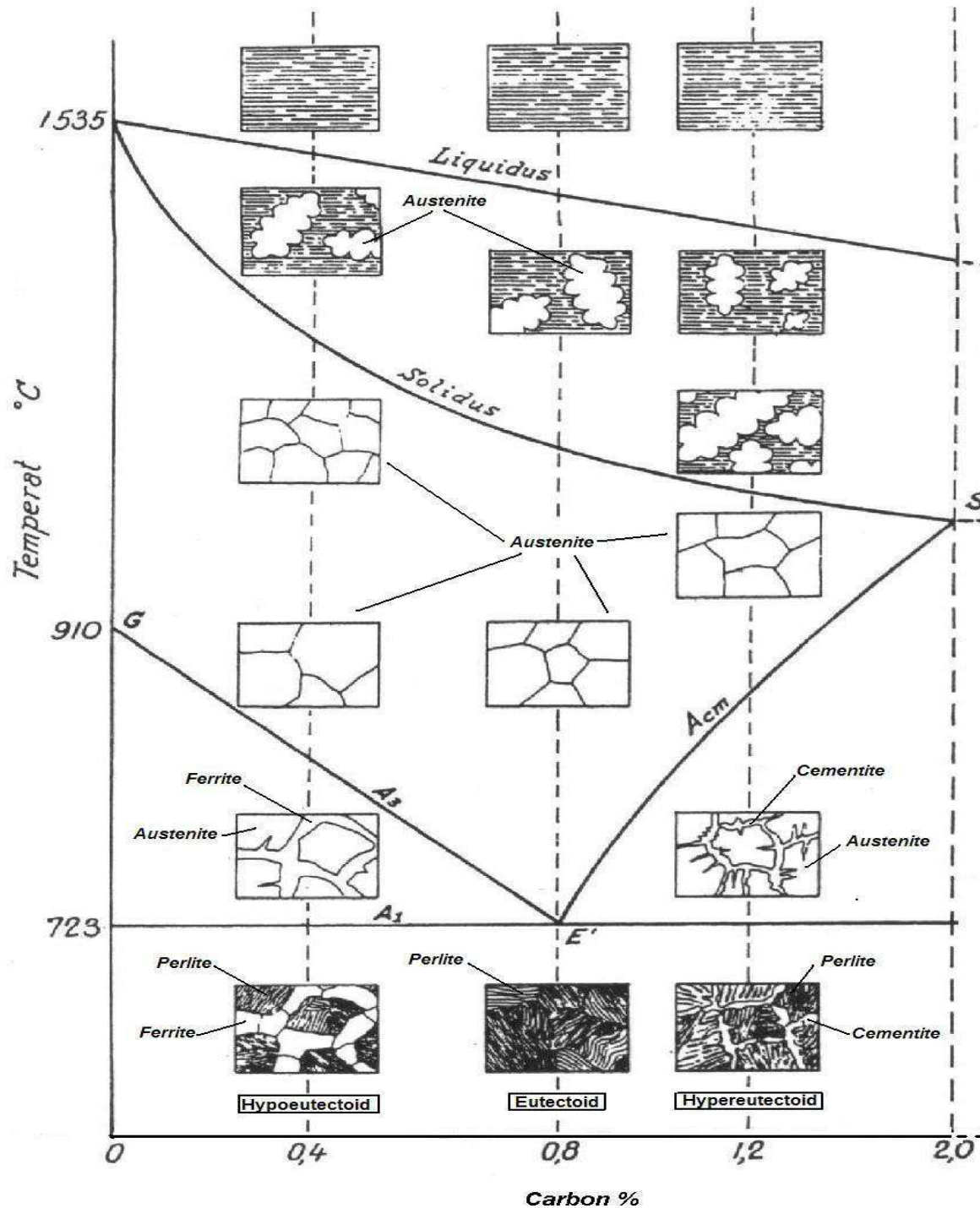
À VISTA
15900
TOTAL A PRAZO

CARTÃO EXTRA

51 JORNOS

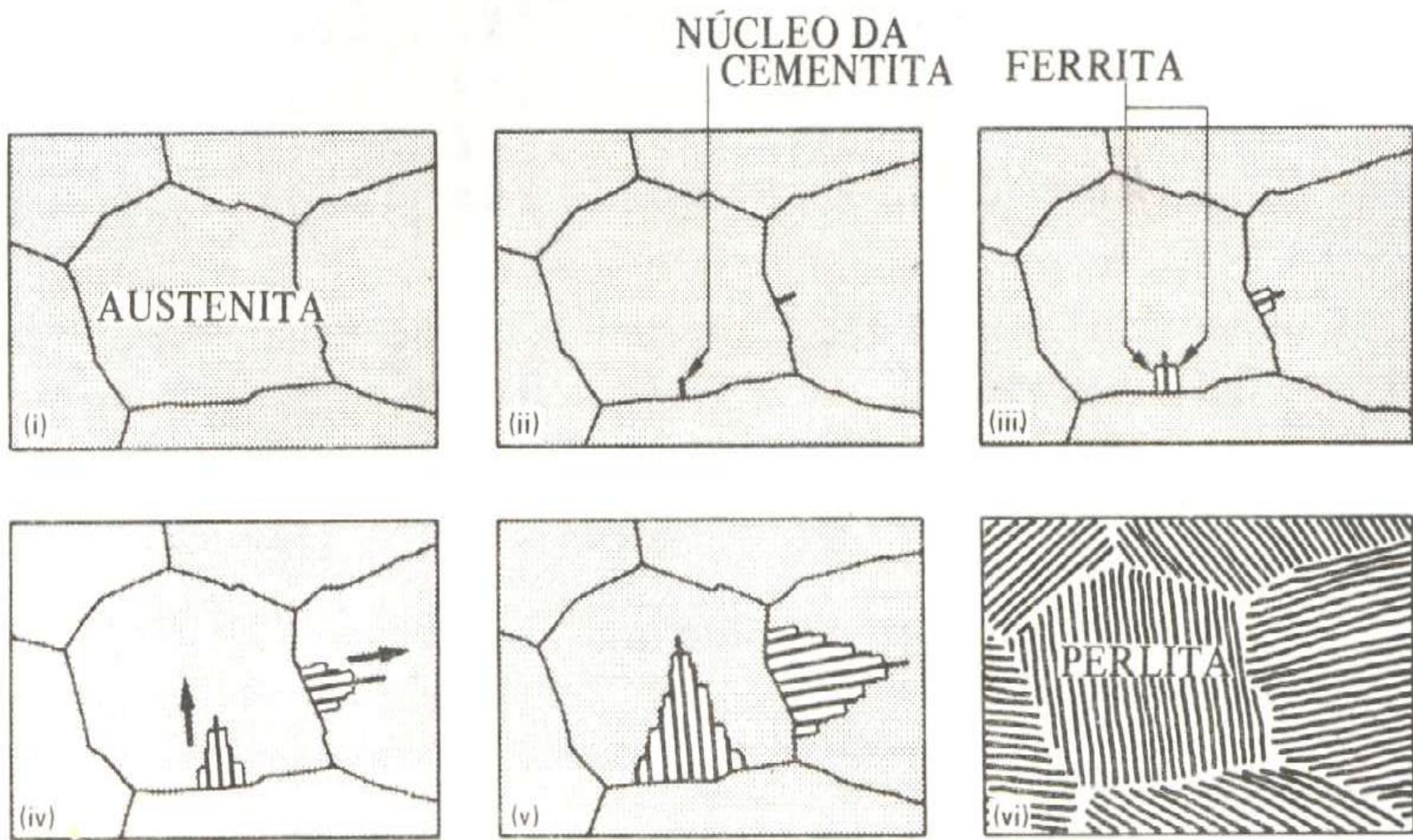


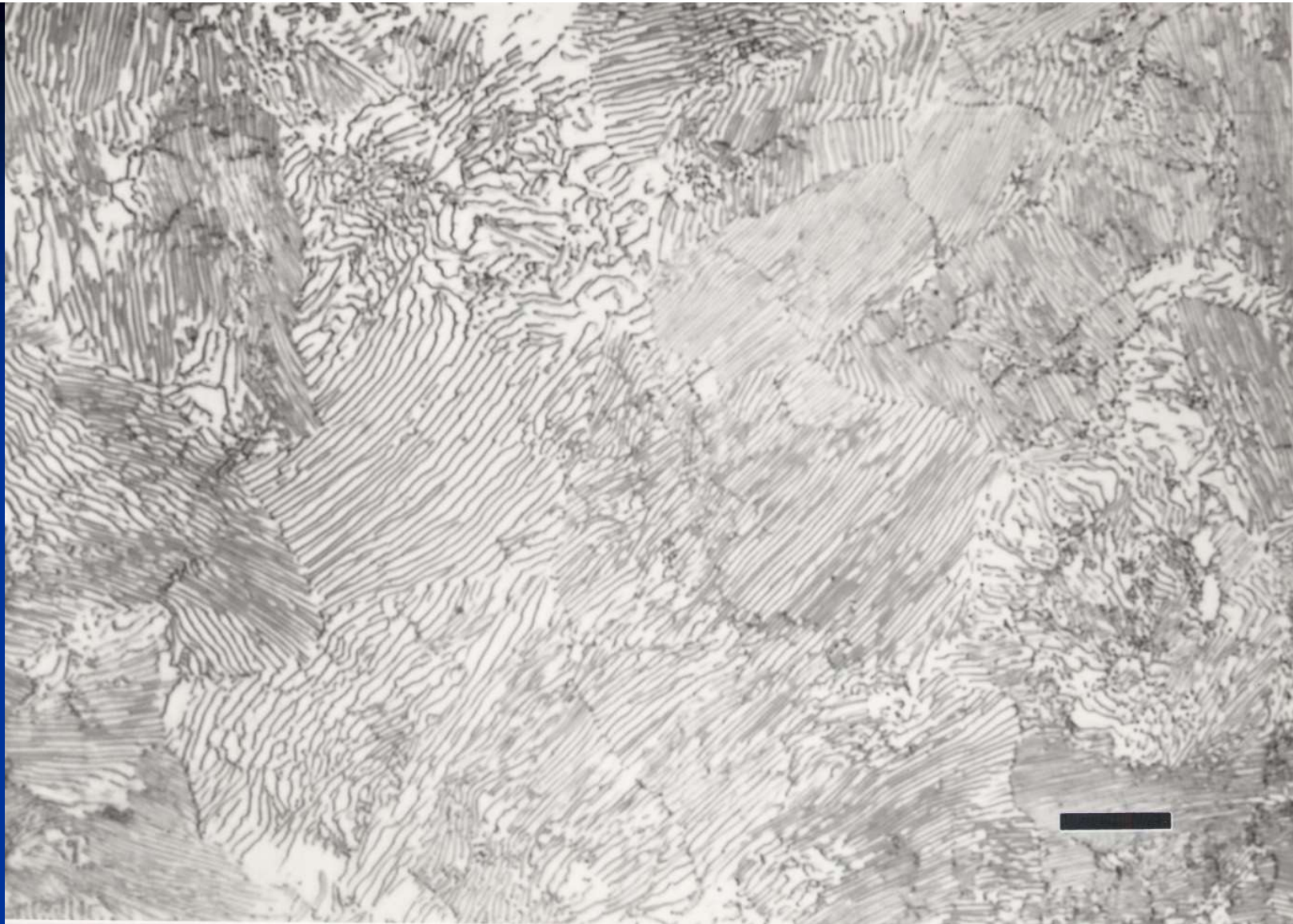




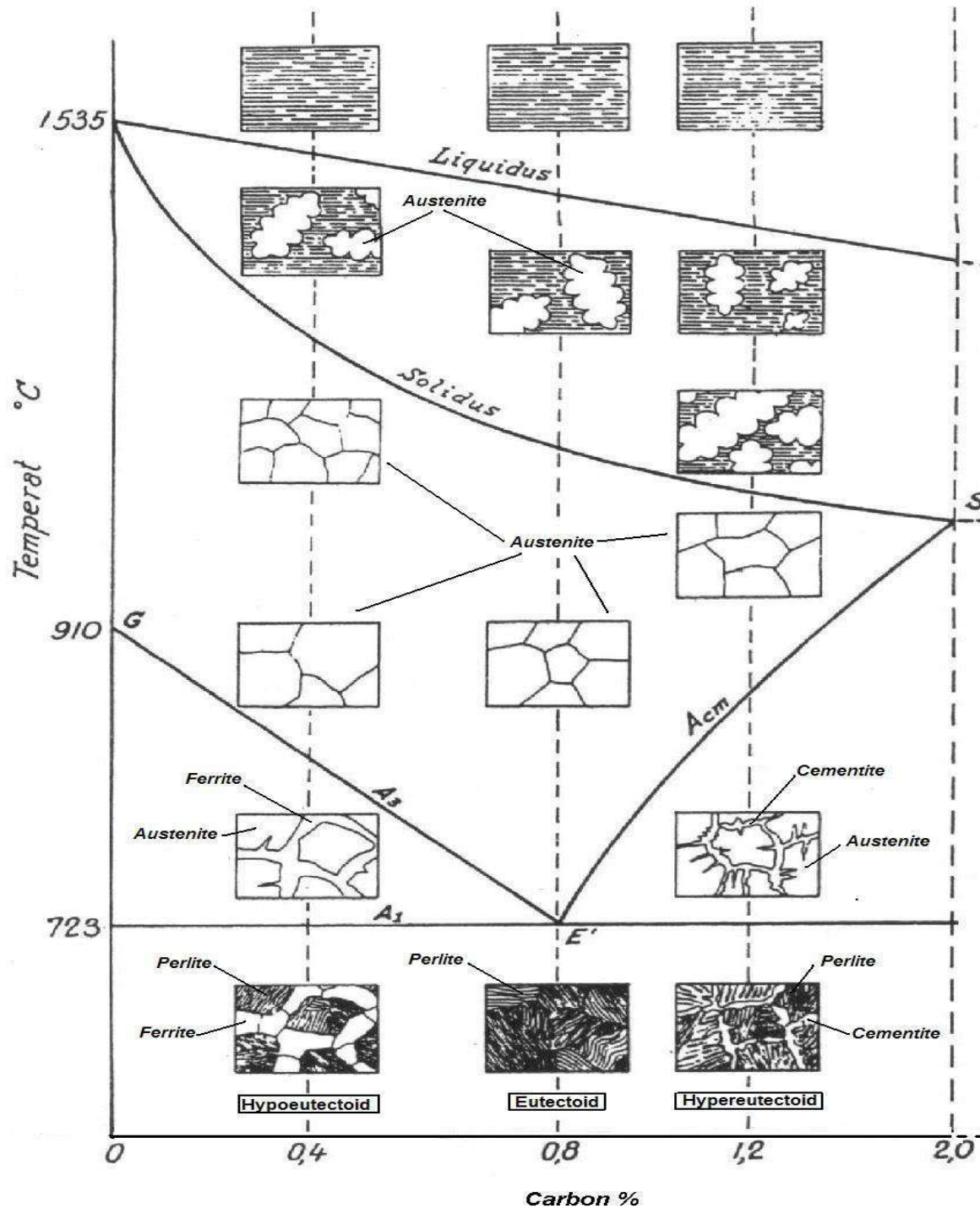
A1: Temperatura de equilíbrio de início de austenitização

A3: Temperatura de equilíbrio de fim de austenitização





Coarse lamellar pearlite in a hot-rolled Fe – 0.8% C binary alloy.
Picral etch. Magnification bar is 20 μm in length.



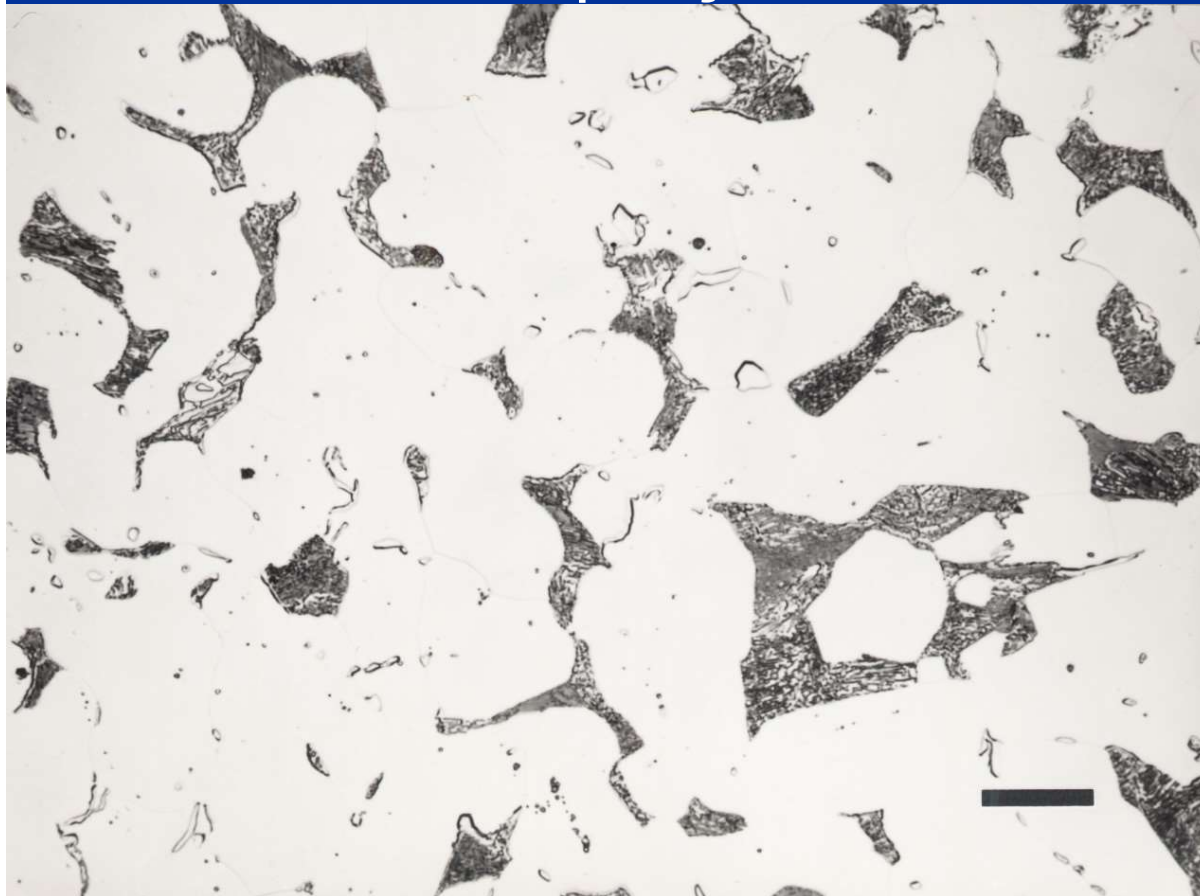
A1: Temperatura de equilíbrio de início de austenitização

A3: Temperatura de equilíbrio de fim de austenitização

LIGAS HIPOEUTETÓIDES

- A ferrita estará presente tanto na perlita como na fase que se formou enquanto se resfriava antes da temperatura do eutetóide. A ferrita que está presente na perlita é chamada ferrita eutetóide e a ferrita que se formou antes da temperatura do eutetóide é chamada ferrita proeutetóide.

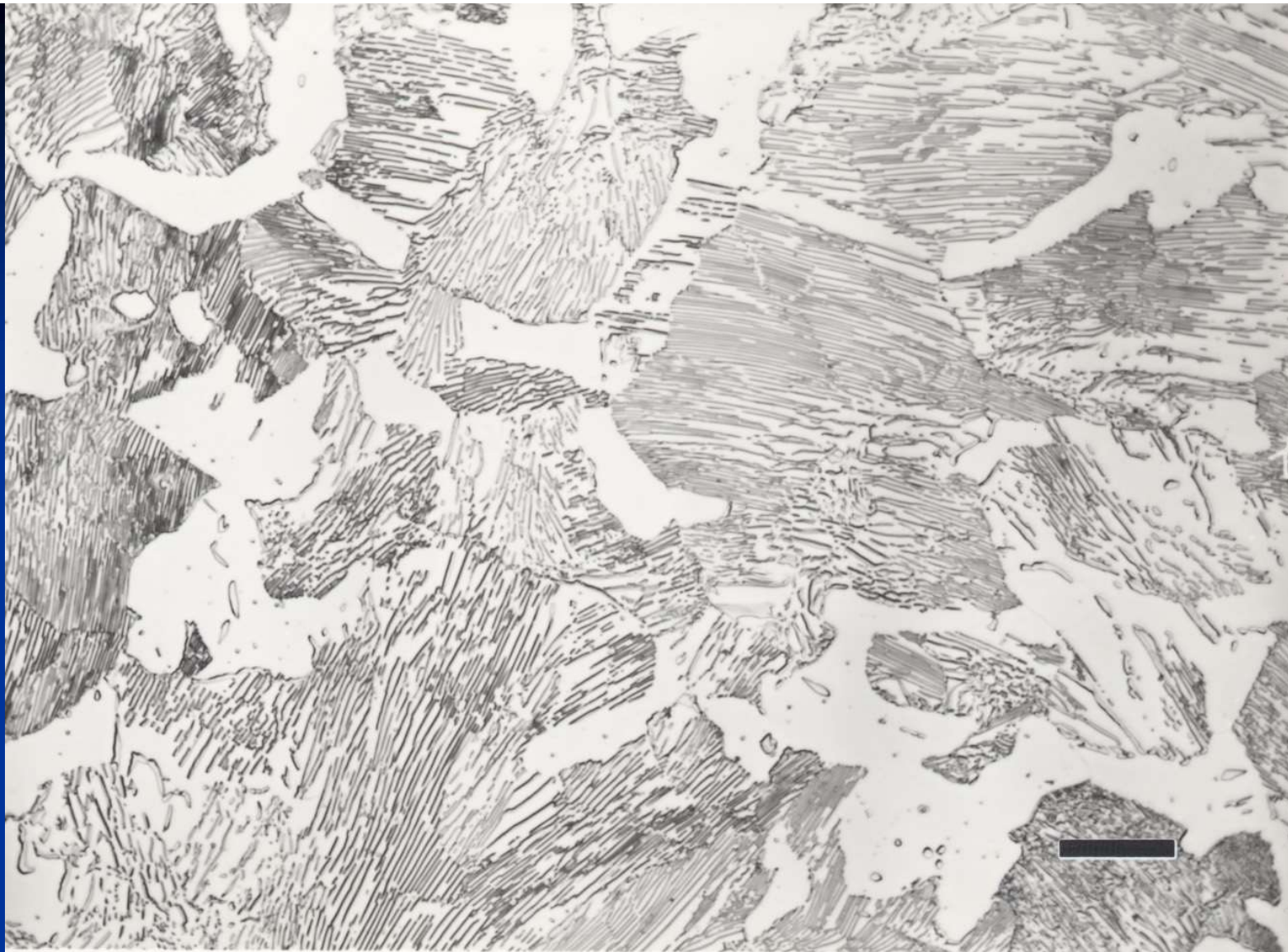
•As regiões brancas correspondem à ferrita proeutetóide. Para a perlita, o espaçamento entre as camadas α e Fe_3C varia de grão para grão; uma parte da perlita parece escura, pois as muitas camadas com pequeno espaçamento não estão resolvidas e definidas na ampliação da fotomicrografia abaixo.



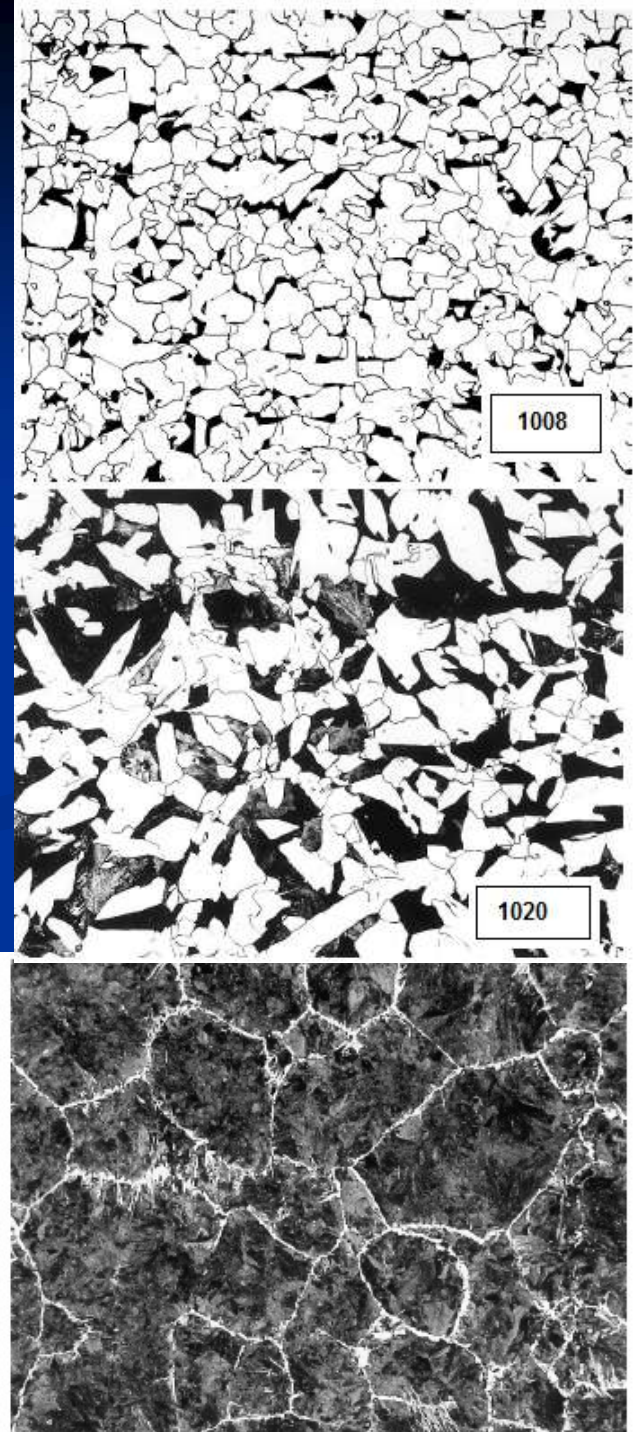
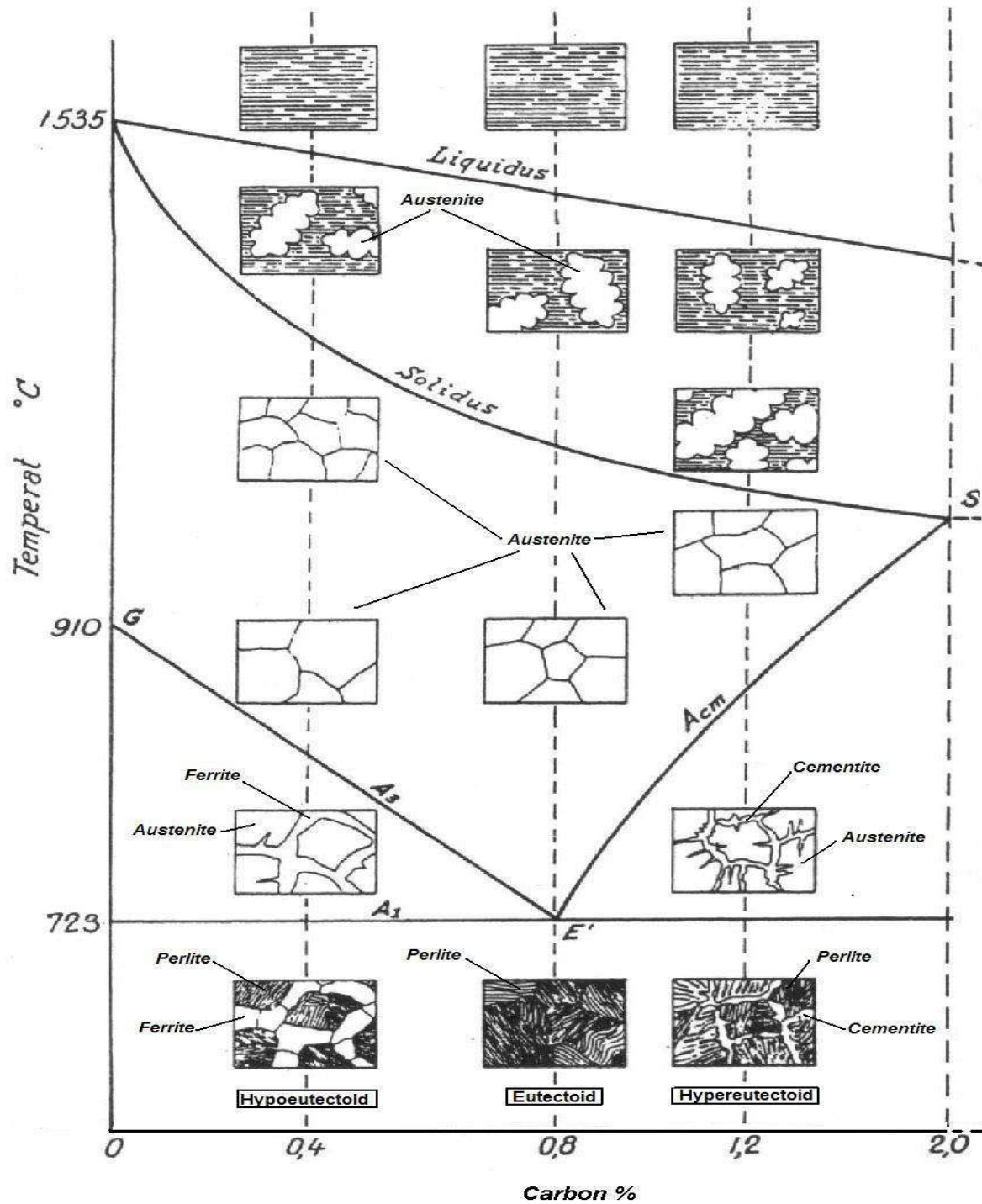
Ferrite (white) and pearlite in a hot-rolled Fe – 0.2% C binary alloy. Picral etch. Magnification bar is 20 μm in length.

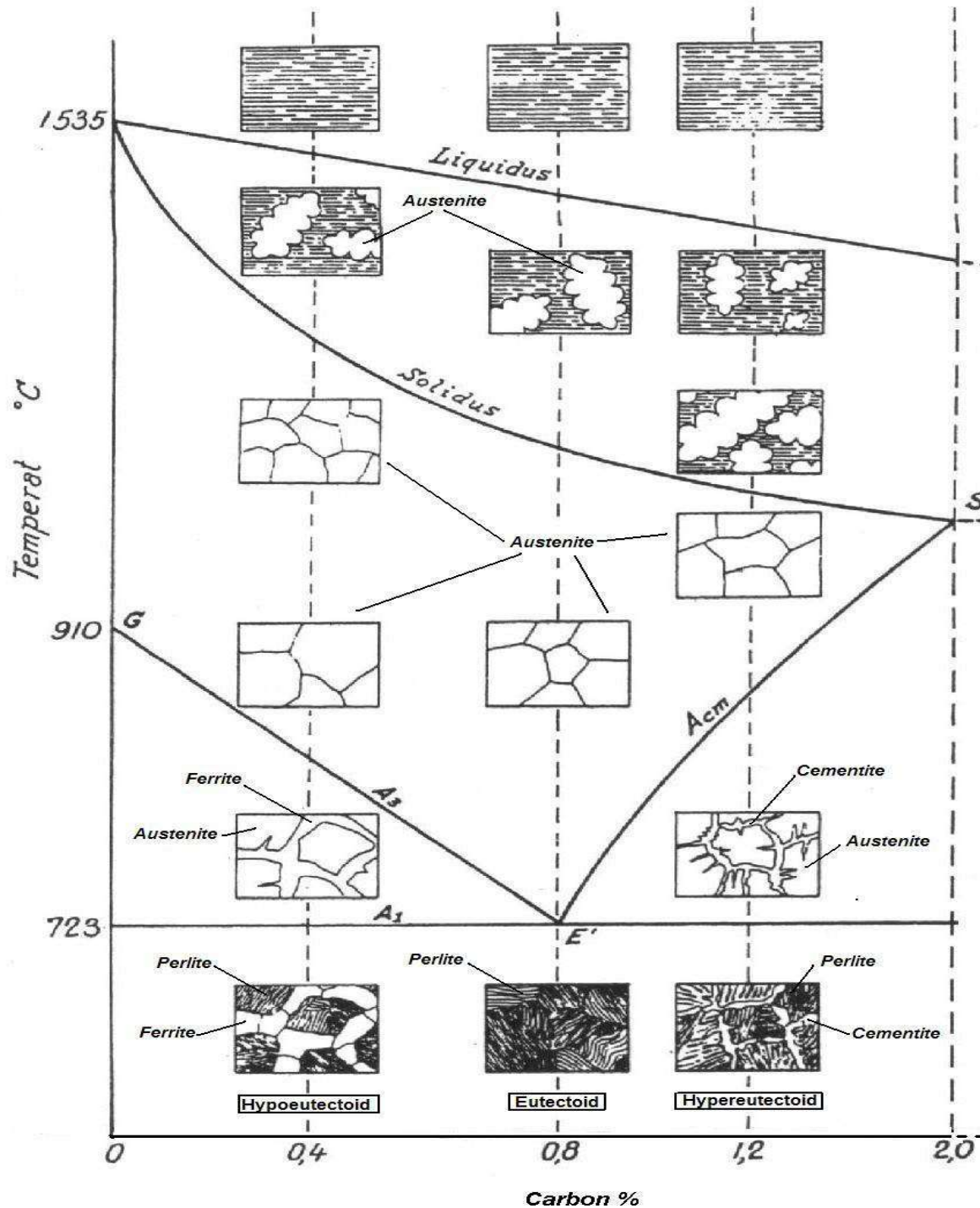


Ferrite (white) and pearlite in a hot-rolled Fe – 0.4% C binary alloy.
Picral etch. Magnification bar is 20 μm in length.



Ferrite (white) and pearlite in a hot-rolled Fe – 0.6% C binary alloy. Picral etch. Magnification bar is 20 μm in length.



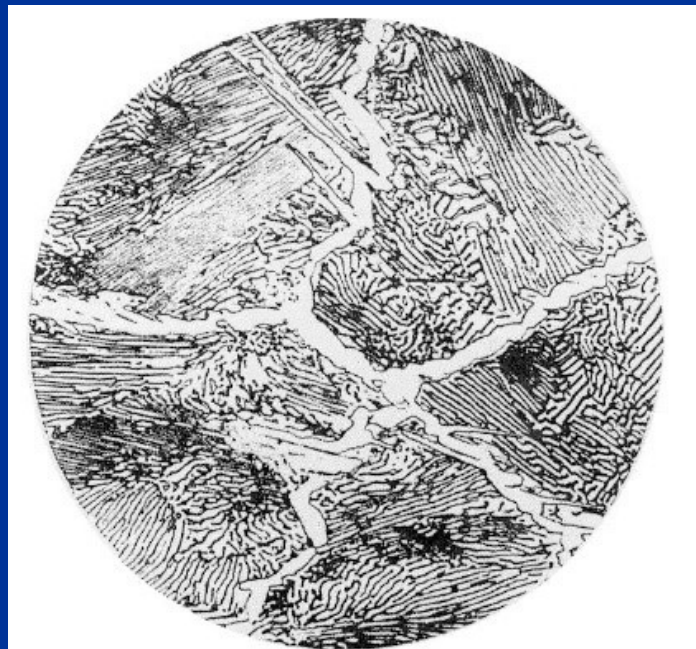


A1: Temperatura de equilíbrio de início de austenitização

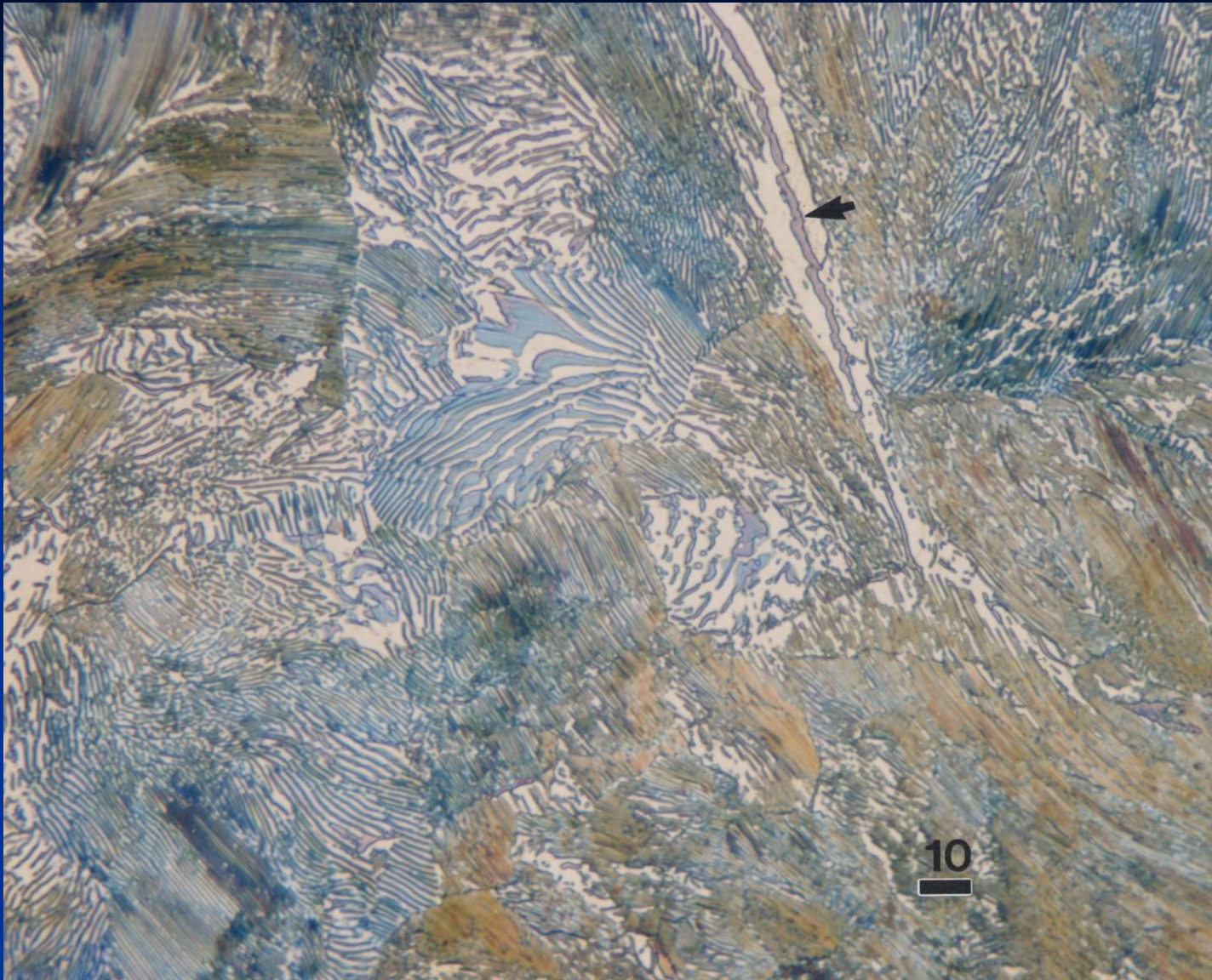
A3: Temperatura de equilíbrio de fim de austenitização

LIGAS HIPEREUTETÓIDES

- A cementita formada antes do eutetóide é chamada cementita proeutetóide e a microestrutura das ligas hipereutetóides resultam em perlita + cementita proeutetóide
- Na fotomicrografia de um aço hipereutetóide a cementita proeutetóide aparece clara e nos contornos de grãos.



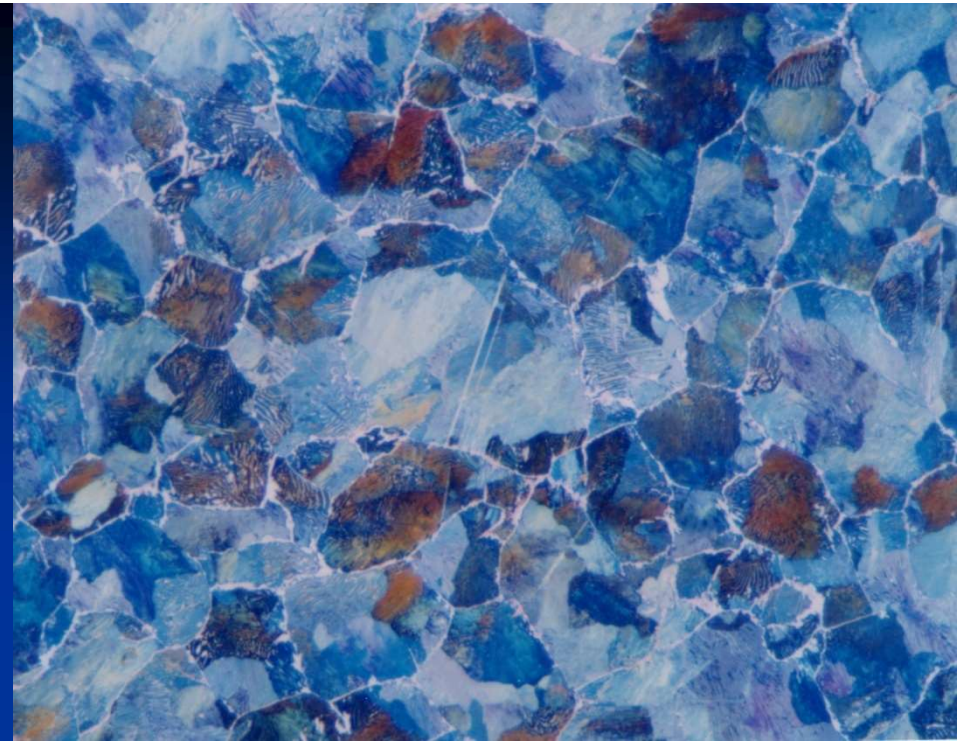
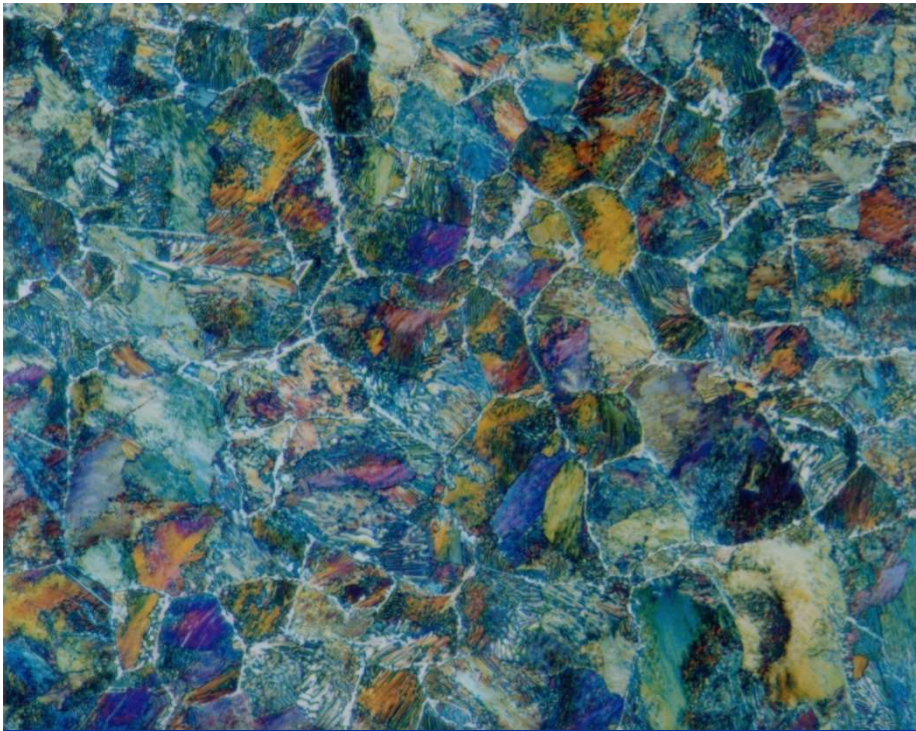
Pearlite and G.B. Cementite in an hypereutectoid steel
cementite appears white



Microstructure of as-rolled Fe – 1% C binary alloy tint etched with Beraha's sodium molybdate reagent to color cementite. The arrow points of proeutectoid cementite that precipitated on a prior-austenite grain boundary before the eutectoid reaction (austenite forms ferrite and cementite in the form of lamellar pearlite). Magnification bar is 10 μm long.

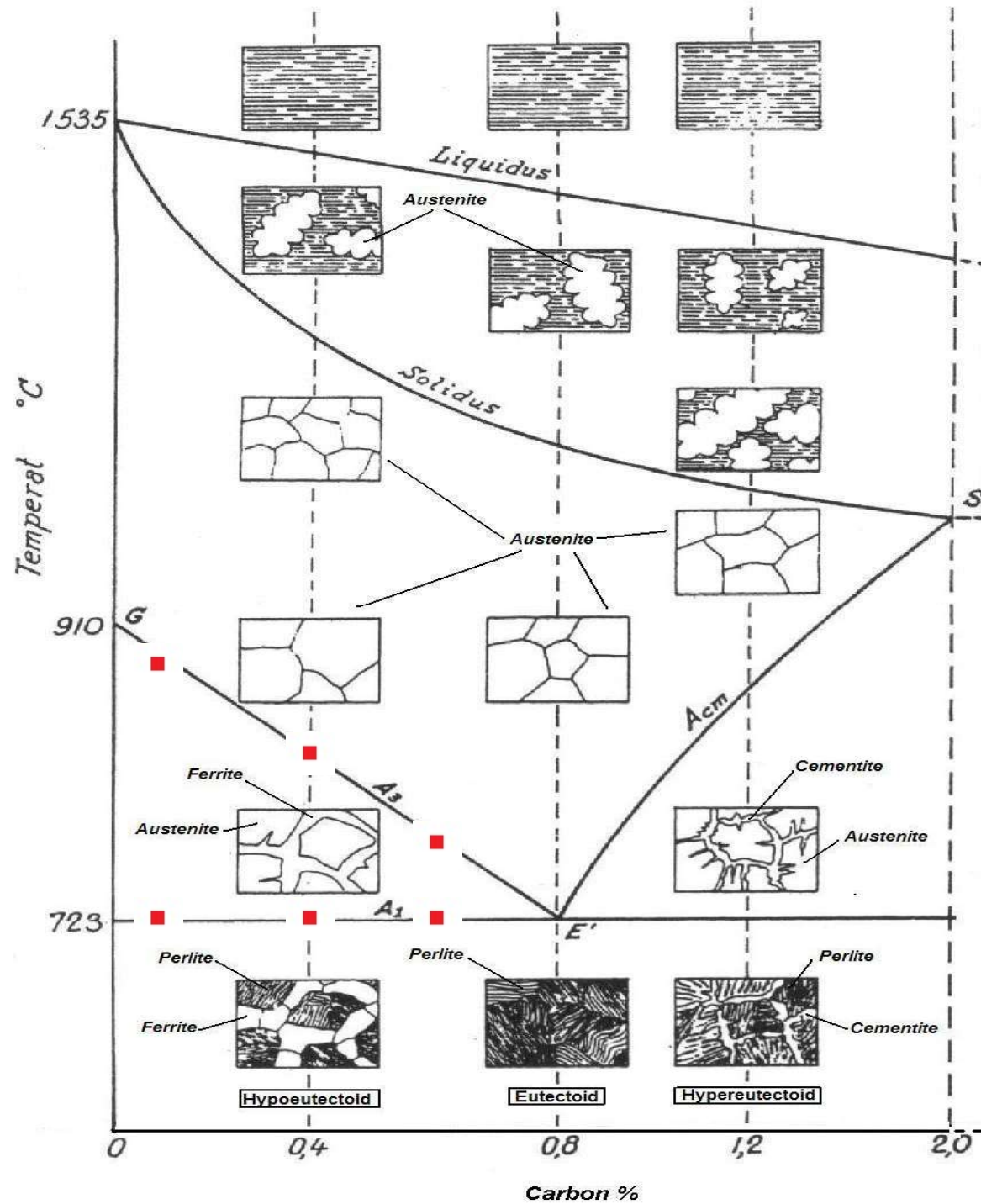


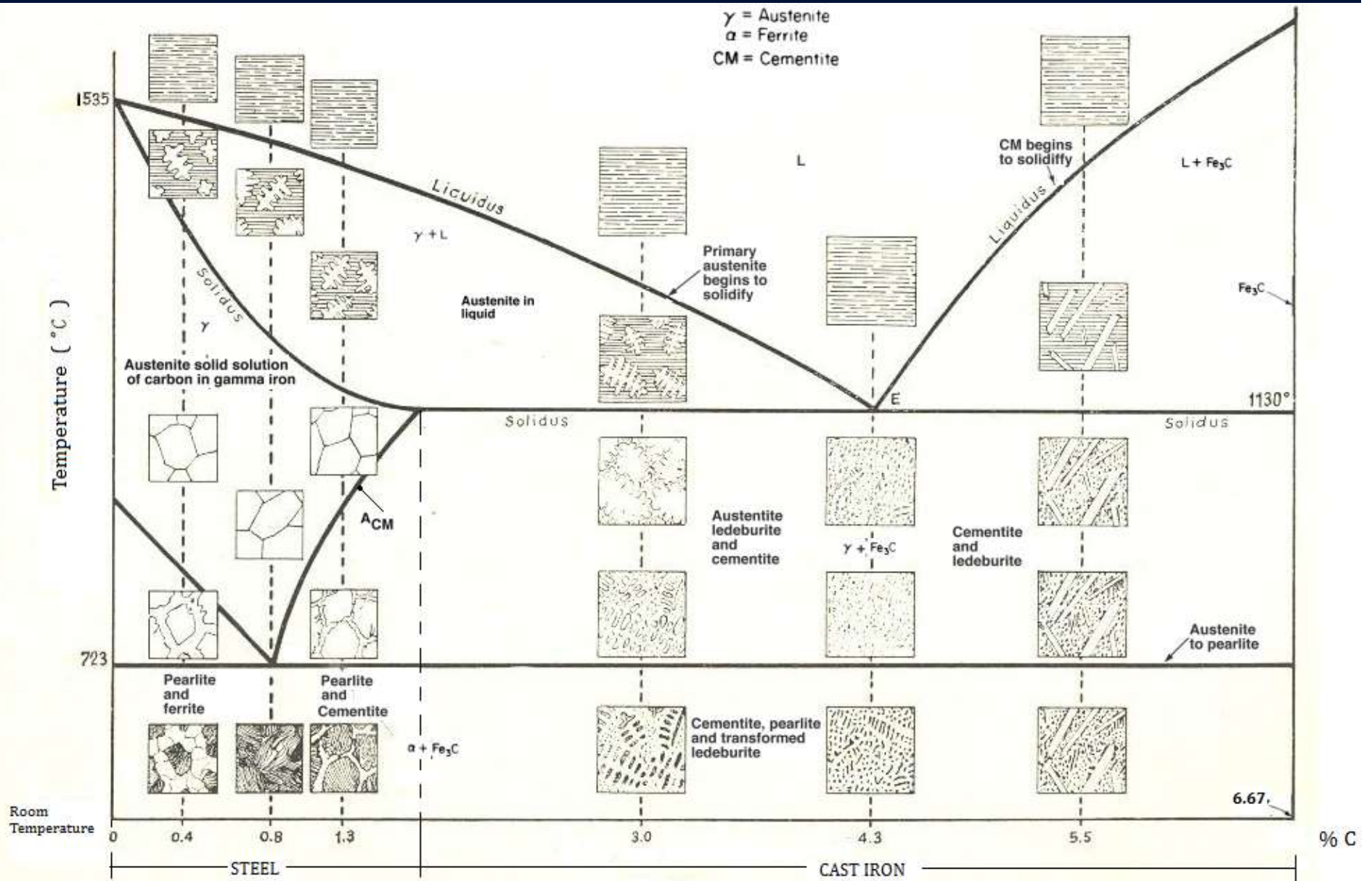
Microstructure of the as-rolled Fe – 1.31% C – 0.35% Mn – 0.25% Si specimen with the intergranular carbide network clearly visible after etching with alkaline sodium picrate, 90 °C – 60 s. Original at 500X magnification.



Color etching of the as-rolled hypereutectoid Fe-1.31% C – 0.35% Mn – 0.25% Si specimen clearly revealed the intergranular cementite films. Beraha's sulfamic acid etch (100 mL water, 3 g $K_2S_2O_5$ and 2 g NH_2SO_3H) (left) and Klemm's I reagent (right) were used. Original magnifications were 500X. Taken with polarized light and sensitive tint.

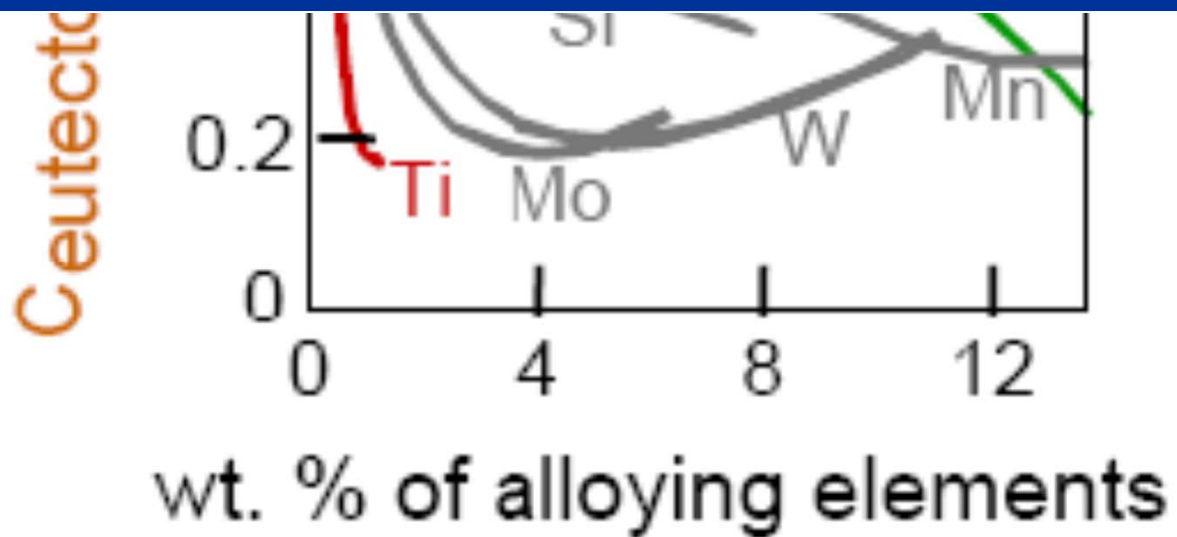
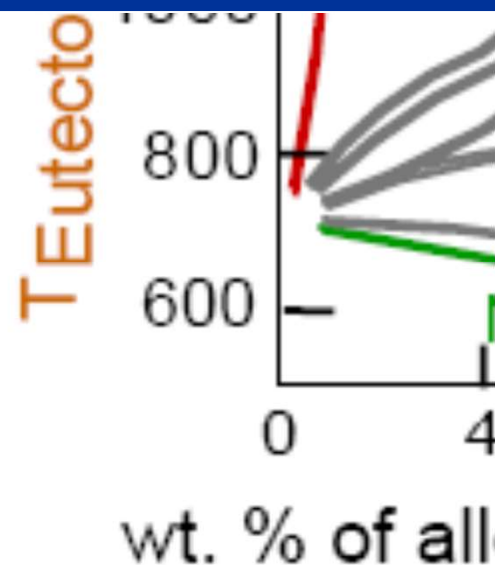
ZONA CRÍTICA

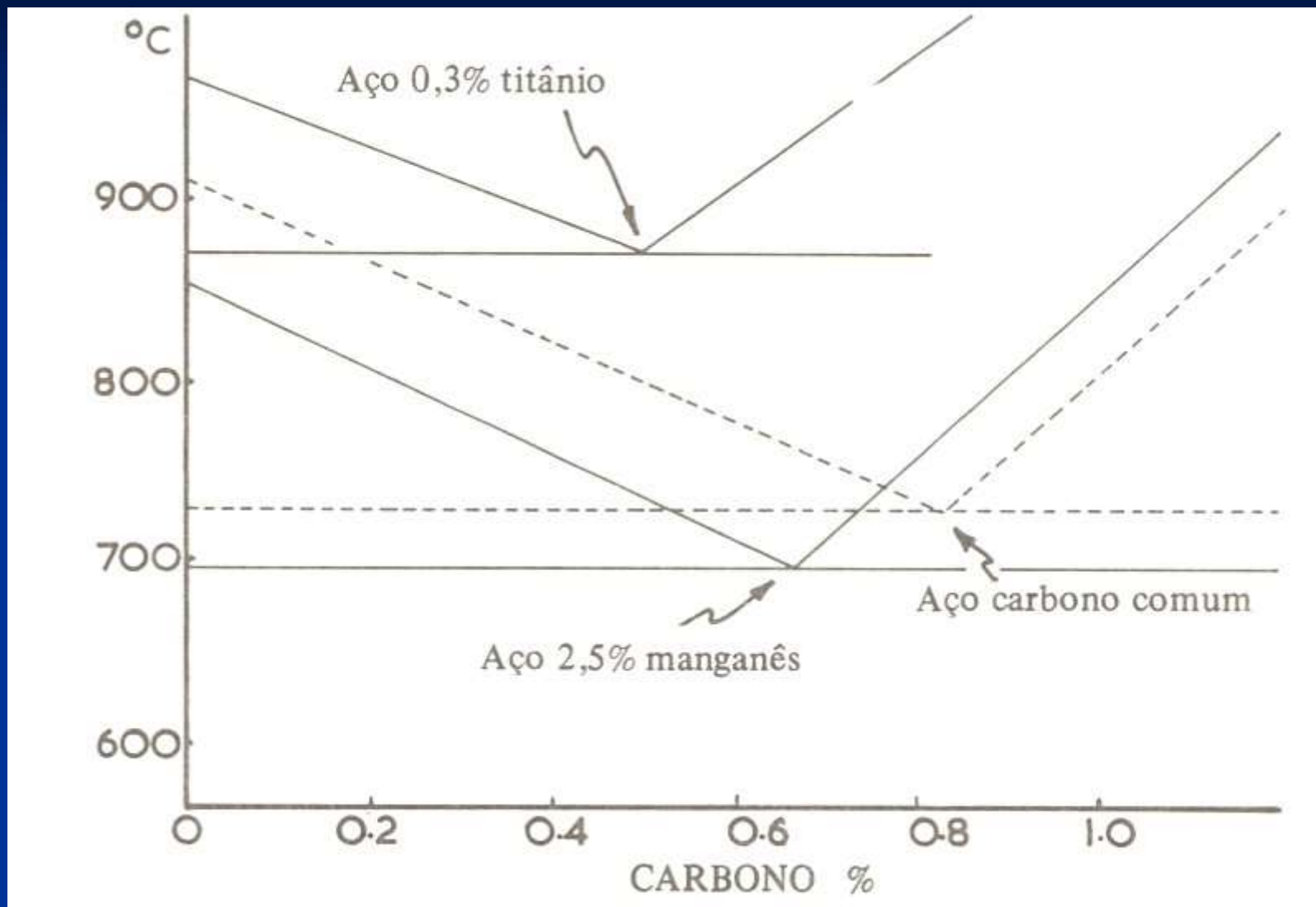


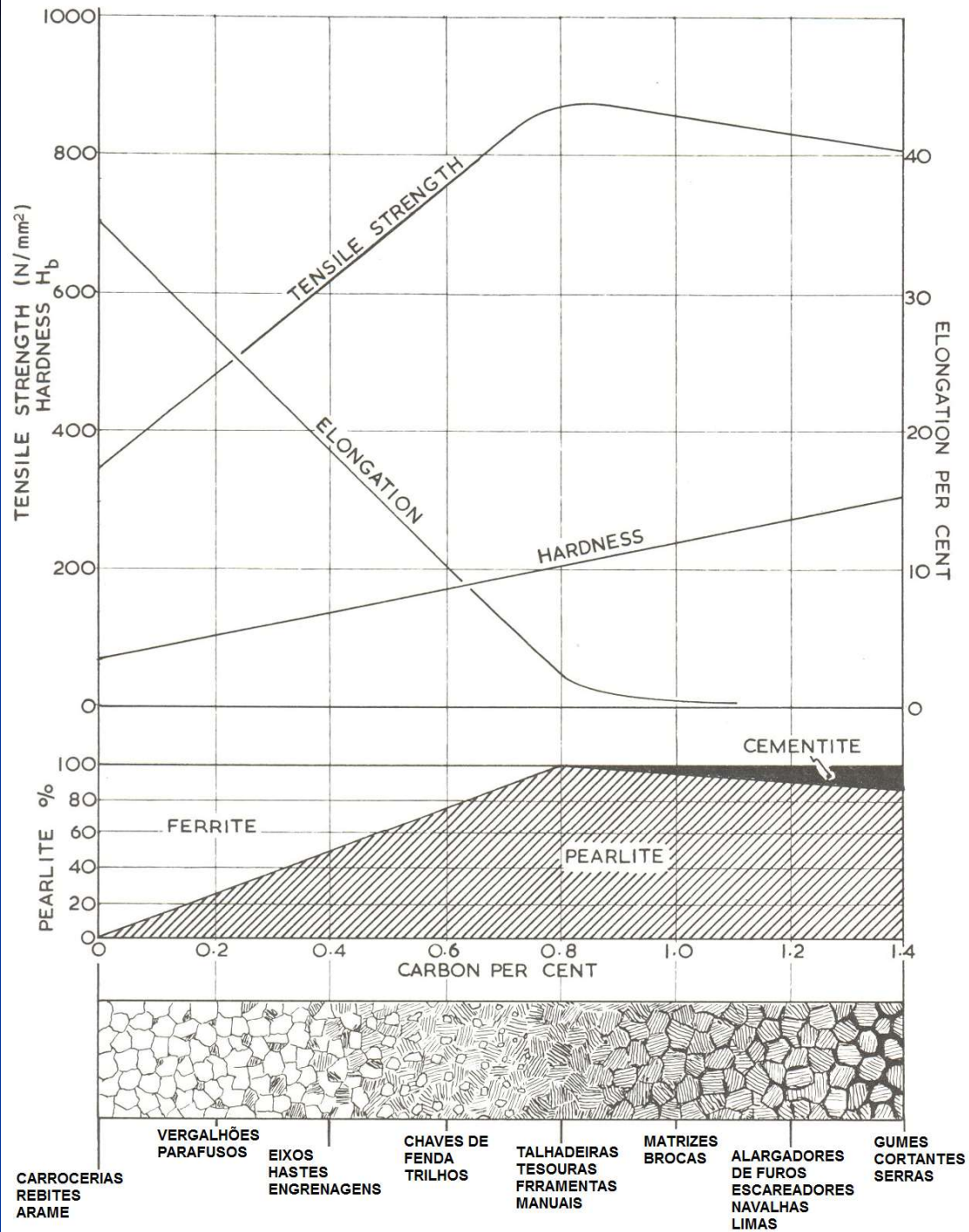


ELEMENTOS DE LIGA NOS AÇOS

- As adições de elementos de ligas (Cr, Ni, Ti, etc.) trazem alterações no diagrama de fases binário para o sistema ferro-cementita. Uma das importantes alterações é o deslocamento da posição eutetóide em relação à temperatura e à concentração de carbono.







Classificação dos aços

	Specifications
SAE-AISI	Society of Automotive Engineers – American Iron and Steel Institute
ASTM (UNS)	American Society for Testing and Materials (www.astm.org)
ASME	American Society of Mechanical Engineers
MIL	U.S. Department of Defense
AMS	Aerospace Materials Specification
BS	British Standards Institution (http://www.bsi-global.com/index.xalter)
EN	European Committee for Standardization (http://www.cenorm.be)

- ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS.

MESMA CLASSIFICAÇÃO SAE

Os sistemas mais amplamente usados: SAE AISI

- Numérico
 - Society of Automotive Engineers (SAE)
 - American Iron and Steel Institute (AISI)
- Dois primeiros dígitos indicam o tipo do aço
 - 2nd dígito geralmente dão a quantidade aproximada do elemento de liga predominante
- Os últimos dois dígitos geralmente indicam a quantidade aproximada de carbono

AISI-SAE

Type and Description

Carbon steels

10xx	Plain Carbon (Mn. 1.00% max.)
11xx	Resulfurized
12xx	Resulfurized and rephosphorized
15xx	Plain Carbon (max. Mn. range 1.00-1.65%)

Manganese steels

13xx Mn 1.75

Nickel steels

23xx Ni 3.50

25xx Ni 5.00

Nickel-chromium steels

31xx Ni 1.25; Cr 0.65, 0.80

32xx Ni 1.75; Cr 1.07

33xx Ni 3.50; Cr 1.50, 1.57

34xx Ni 3.00; Cr 0.77

Molybdenum steels

40xx Mo 0.20, 0.25

44xx Mo 0.40, 0.52

Chromium-molybdenum steels

41xx Cr 0.50, 0.80, 0.95; Mo 0.12, 0.20, 0.25, 0.30

Nickel-chromium-molybdenum steels

43xx	Ni 1.82; Cr 0.50, 0.80; Mo 0.25
47xx	Ni 1.05; Cr 0.45; Mo 0.20, 0.35
81xx	Ni 0.30; Cr 0.40; Mo 0.12
86xx	Ni 0.55; Cr 0.50; Mo 0.20
87xx	Ni 0.55; Cr 0.50; Mo 0.25
88xx	Ni 0.55; Cr 0.50; Mo 0.35
93xx	Ni 3.25; Cr 1.20; Mo 0.12
94xx	Ni 0.45; Cr 0.40; Mo 0.12
97xx	Ni 1.00; Cr 0.20; Mo 0.20
98xx	Ni 1.00; Cr 0.80; Mo 0.25

Nickel-molybdenum steels

46xx Ni 0.85, 1.82; Mo 0.20, 0.25

48xx Ni 3.50; Mo 0.25

Chromium steels

50xx Cr 0.27, 0.40, 0.50, 0.65

51xx Cr 0.80, 0.87, 0.92, 0.95, 1.00, 1.05

50xxx Cr 0.50; C 1.00 min.

51xxx Cr 1.02; C 1.00 min.

52xxx Cr 1.45; C 1.00 min.

Chromium-vanadium steels

61xx **Cr 0.60, 0.80, 0.95; V 0.10, 0.15**

Tungsten-chromium steels

72xx **W 1.75; Cr 0.75**

Silicon-manganese steels

92xx **Si 1.40, 2.00; Mn 0.65, 0.82, 0.85; Cr 0.00, 0.65**

High-strength low-alloy steels

9xx **Various SAE grades**

Boron steels

xxBxx **B denotes boron steels**

Leaded steels

xxLxx **L denotes leaded steels**

Aços ao C mais frequentemente usados

- SAE 1010: chapas para conformação
- SAE 1020: aplicações de máquinas em geral
- SAE 1040: componentes para têmpera superficial
- ASTM A36: aço estrutural
- SAE 4140: partes de máquinas de alta resistência
- SAE 4340: partes de máquinas de alta resistência
- SAE 8620: componentes para cementação

