Iron-carbon equilibrium system

Fe-C system

Depending on the form of C

Fe_3C – iron-carbide (cementite)
metastable

C – graphite
stable

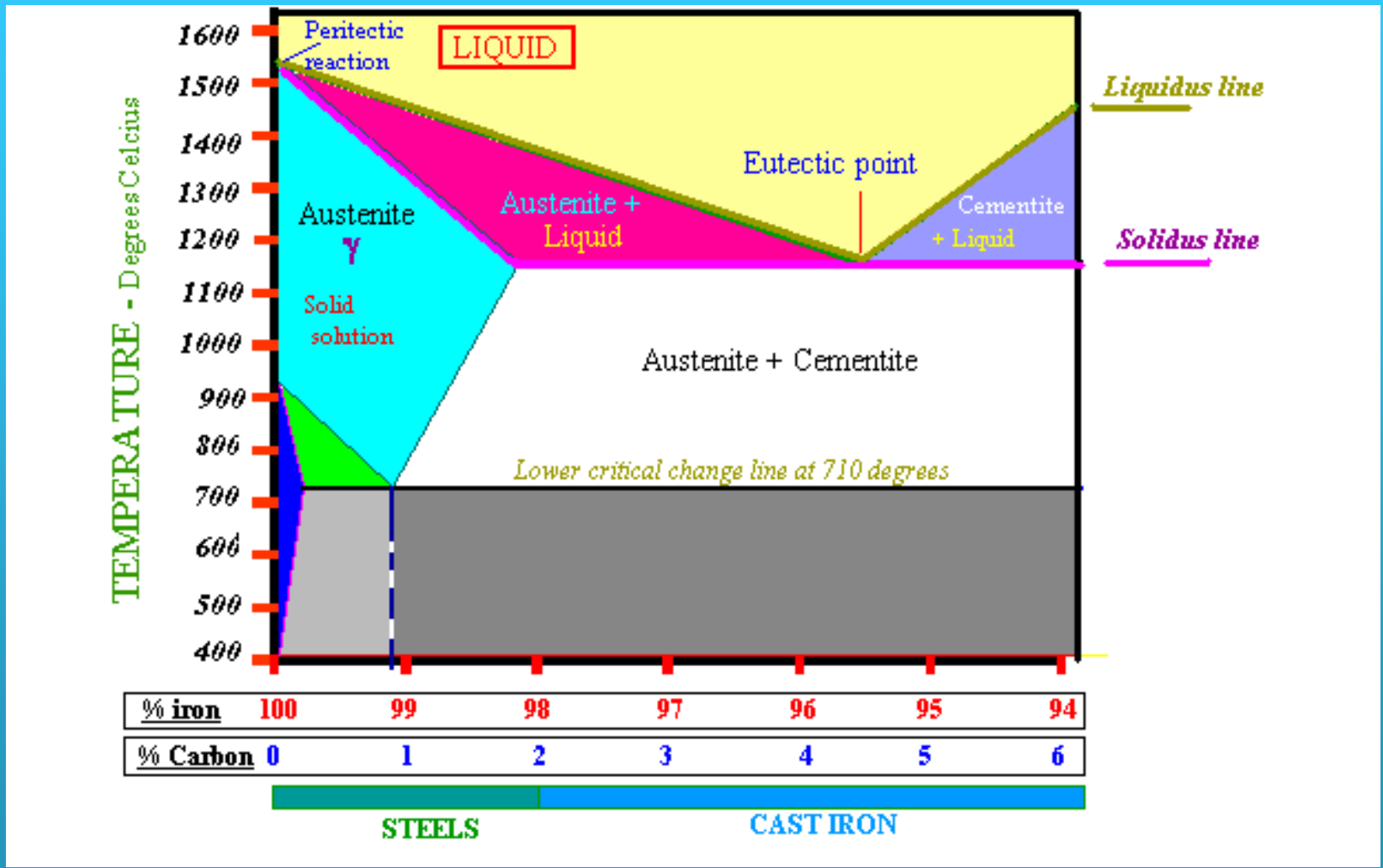
Possible phases

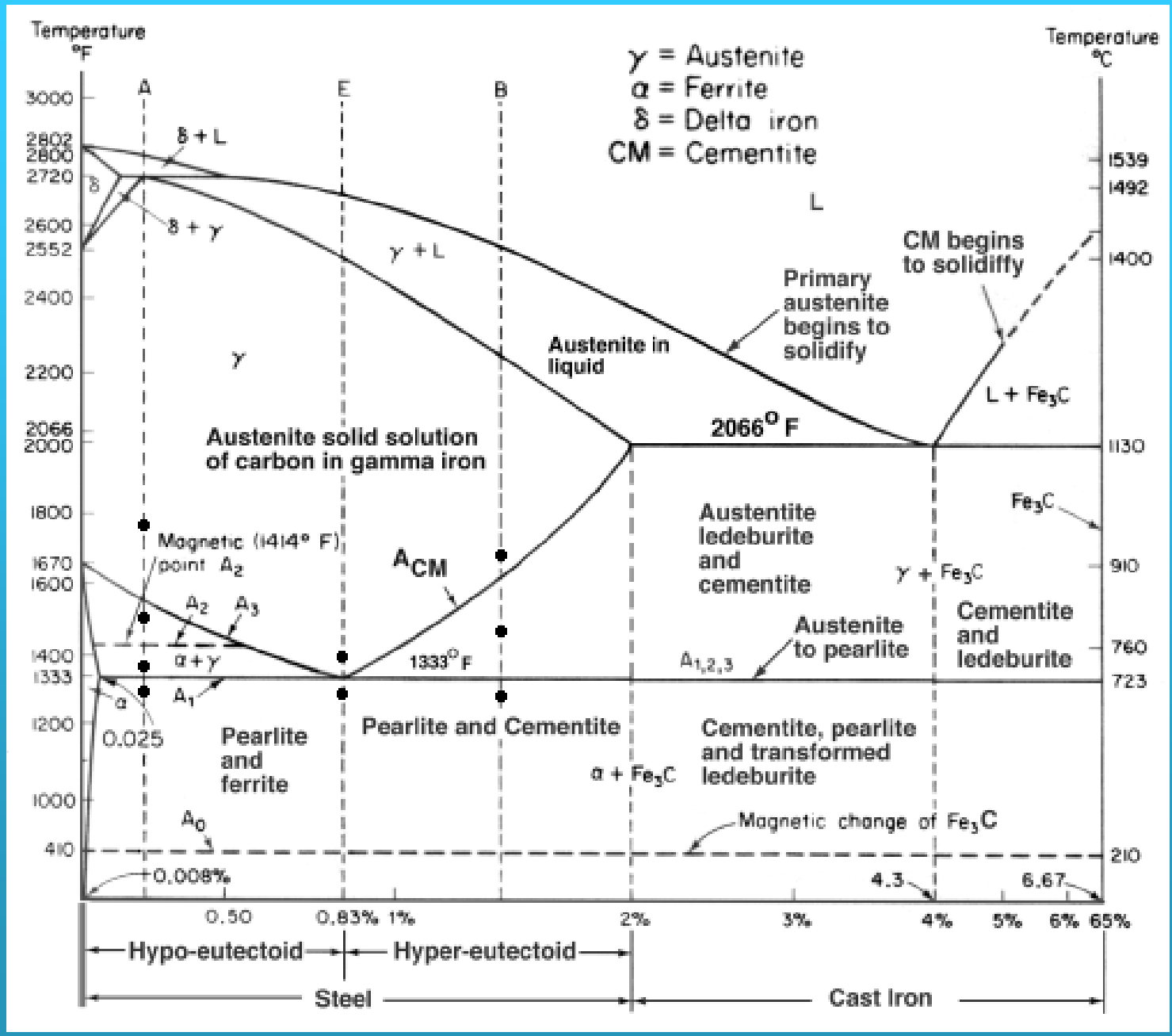
delta iron	delta iron
austenite	austenite
ferrite	ferrite
iron-carbide	graphite

Possible structural constituents:

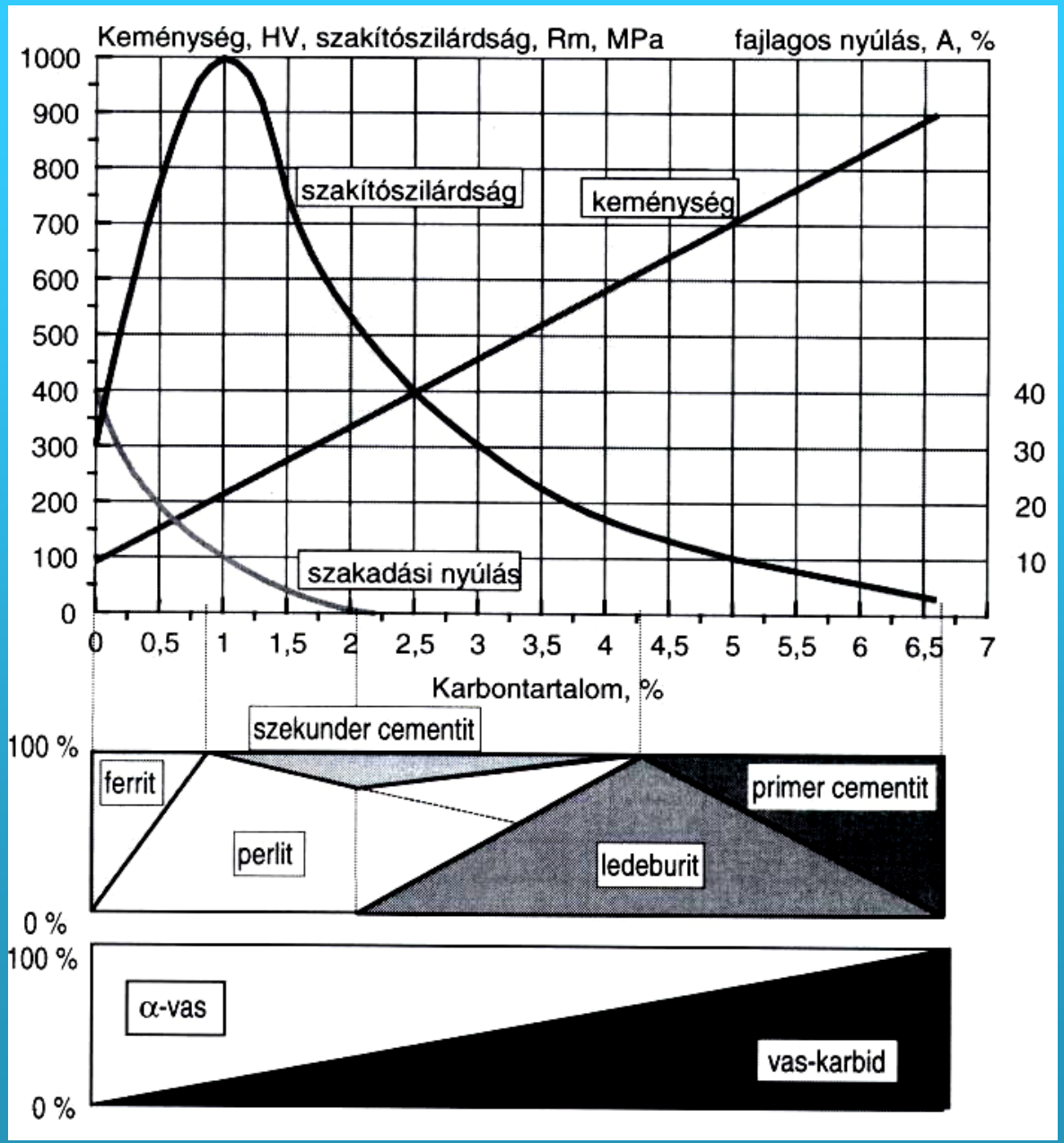
Primary, secondary, tertiary, eutectic, eutectoid iron-carbide	Primary, secondary, tertiary, eutectic, eutectoid graphite
austenite, ferrite,	austenite, ferrite, graphitic eutectic,
ledeburite (eutectic)	and graphitic eutectoid
perlite (eutectoid)	

Iron-Carbon diagram
Metastable system (Fe-Fe_3C)




Temperature °F
Temperature °C
γ = Austenite
α = Ferrite
δ = Delta iron
CM = Cementite
A
E
B
L
δ + L
δ + γ
γ + L
CM begins to solidiffy
Primary austenite begins to solidify
Austenite in liquid
L + Fe3C
2066° F
γ
Austenite solid solution of carbon in gamma iron
Austentite ledeburite and cementite
γ + Fe3C
Cementite and ledeburite
Fe3C
Magnetic (1414° F) point A2
ACM
A2
A3
α + γ
1333° F
A1,2,3
Austenite to pearlite
A1
α
0.025
Pearlite and ferrite
Pearlite and Cementite
α + Fe3C
Cementite, pearlite and transformed ledeburite
A0
Magnetic change of Fe3C
+0.008%
4.3
6.67
3000
2802
2800
2720
2600
2552
2400
2200
2066
2000
1800
1670
1600
1400
1333
1200
1000
410
1539
1492
1400
1130
910
760
723
210
0.50
0.83%
1%
2%
3%
4%
5%
6%
65%
Hypo-eutectoid
Hyper-eutectoid
Steel
Cast Iron

Microstructure and mechanical properties



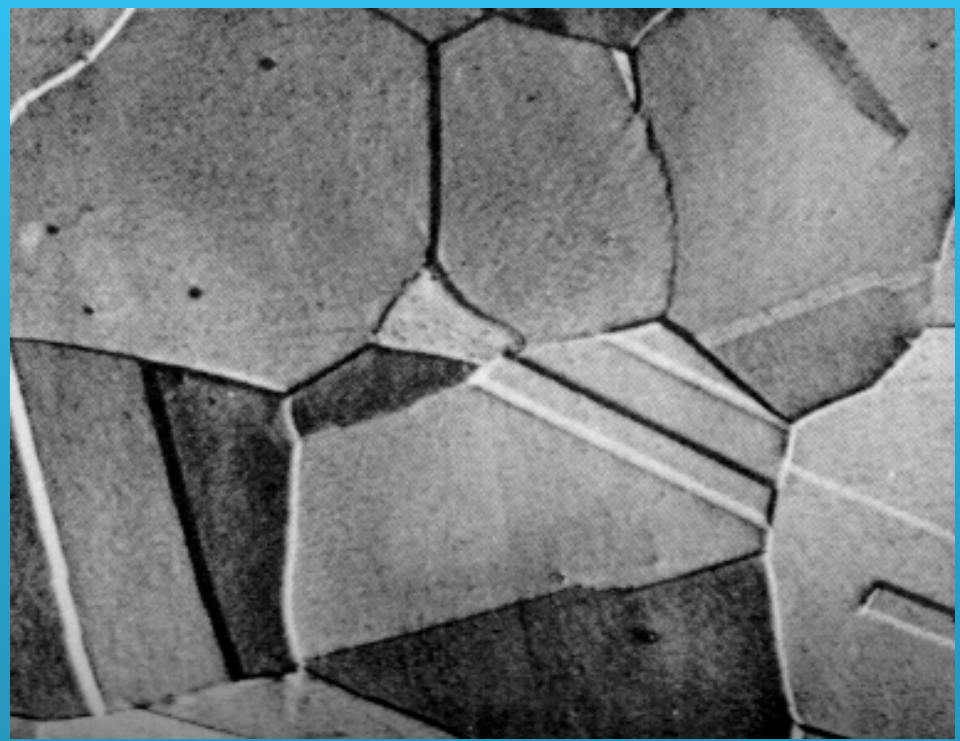
Austenite

-Interstitional solid solution
(C is solved in face centered cubic lattice of Fe)

-Limited solubility

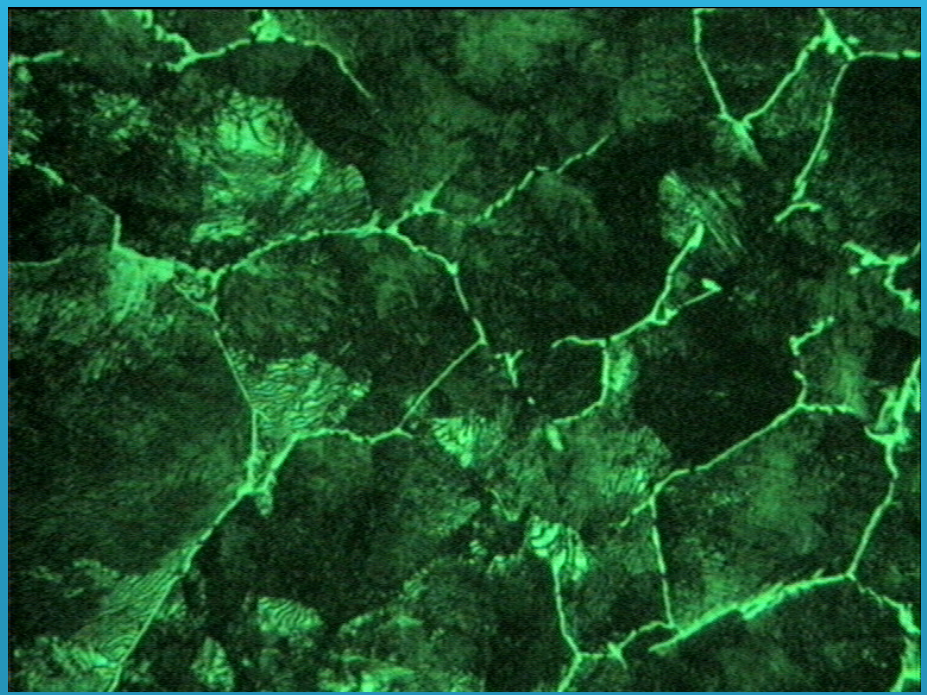
max. solubility:

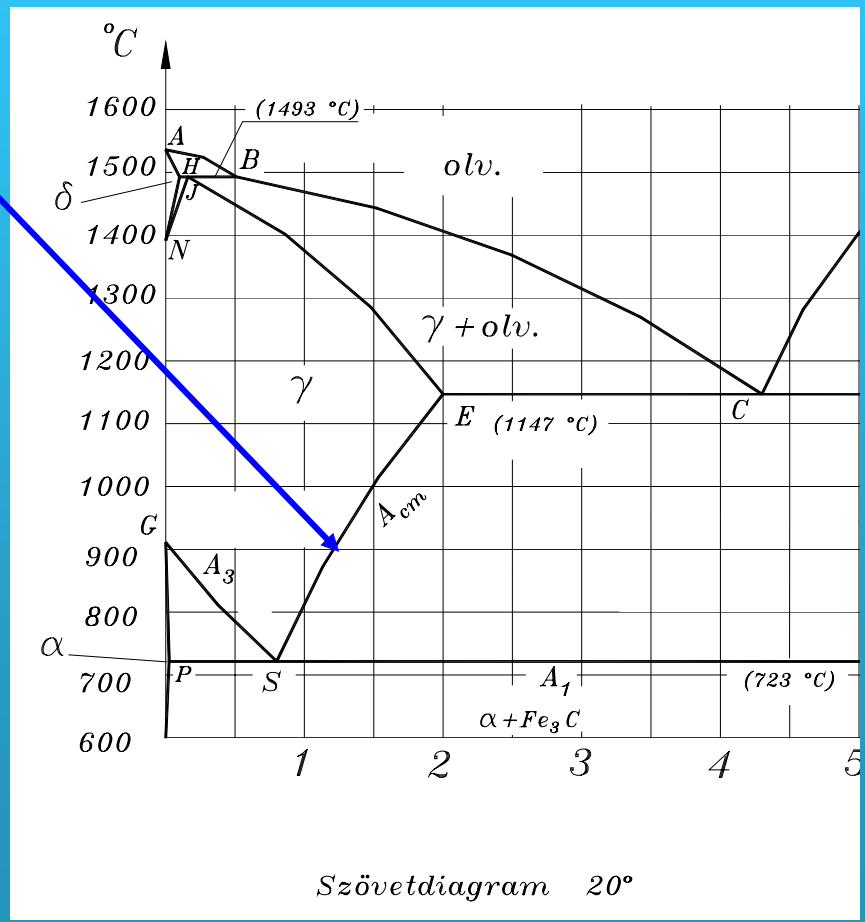
2,06% C at 1147 C°



Transformations in solid state

- **Limited solubility of C in austenite**
- **Iron-carbide segregation**

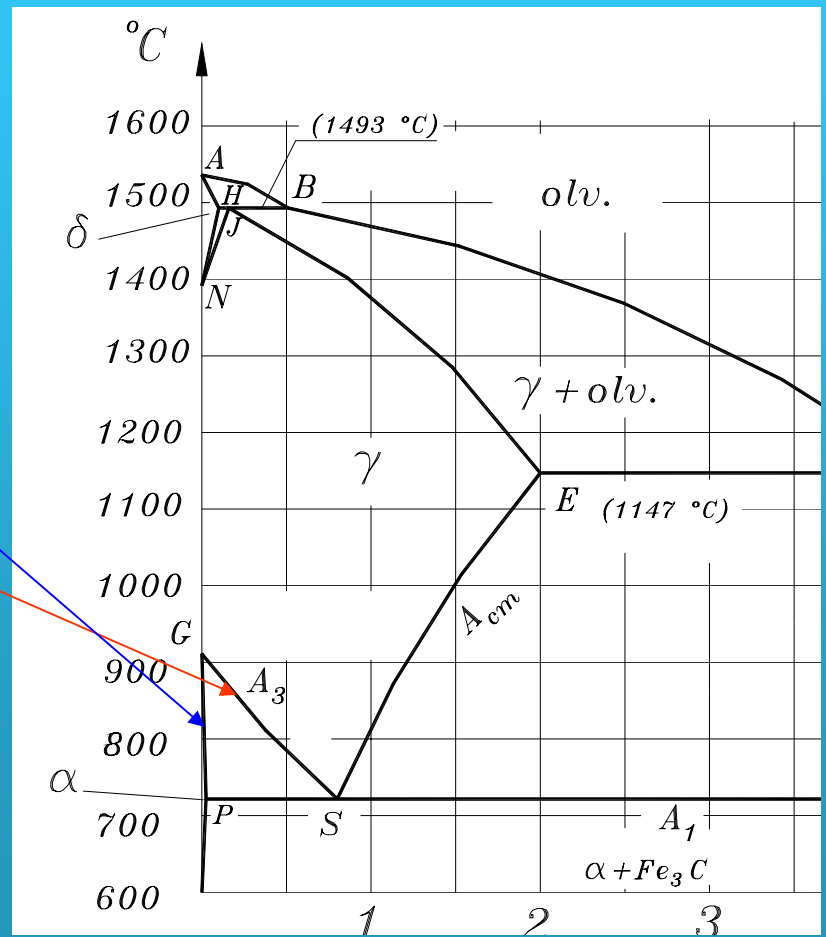




Transformations in solid state

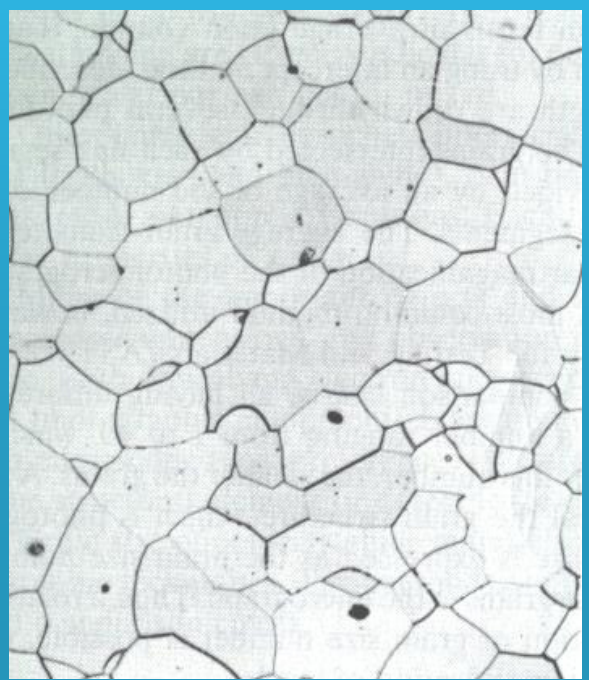
Allotrophic transformation

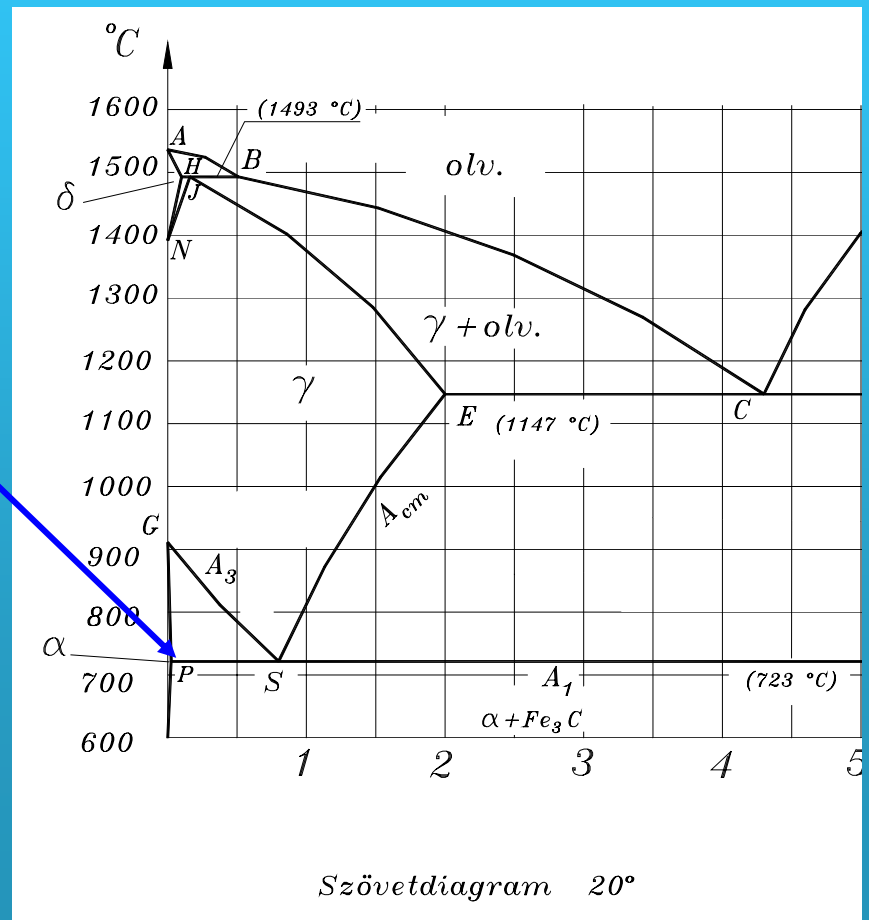
of austenite into ferrite



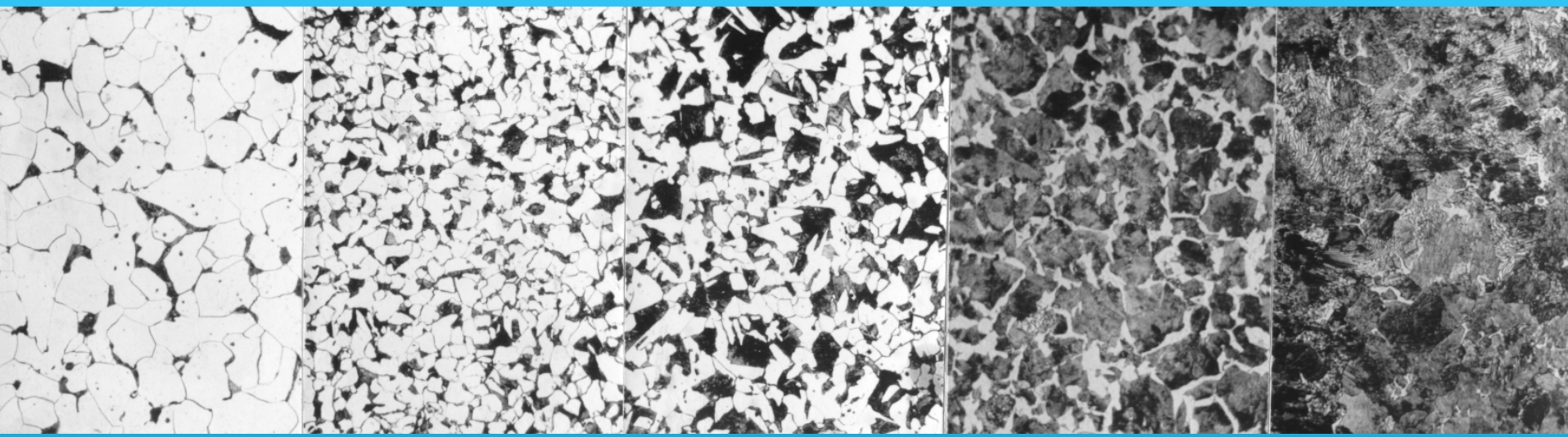
Transformations in solid state

- **Limited solubility of C in ferrite**
- **Iron-carbide segregation**





Effect of C content



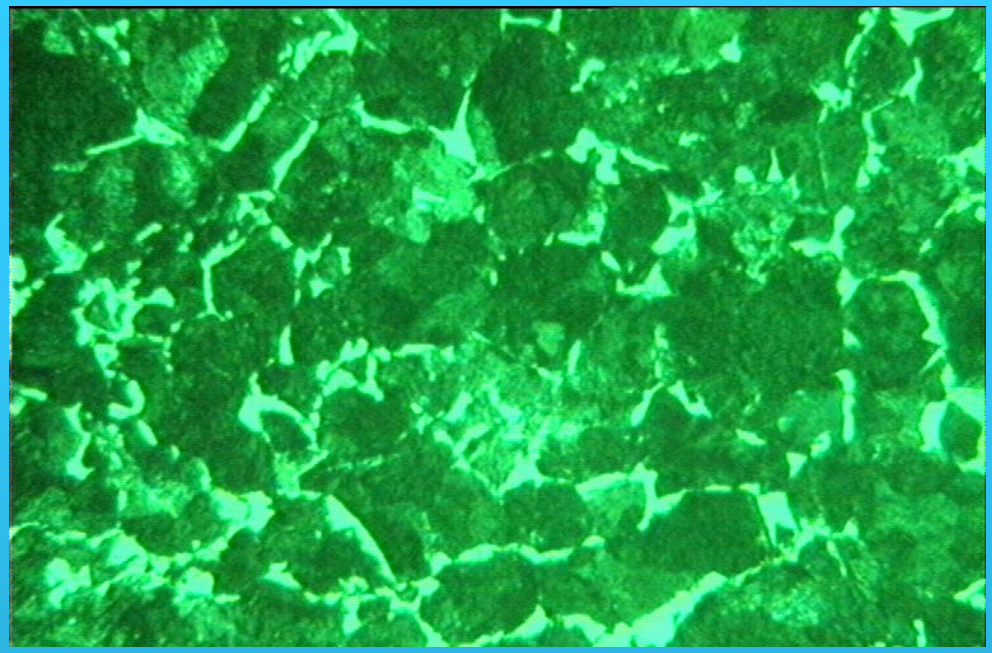
C%=0,1…0,8

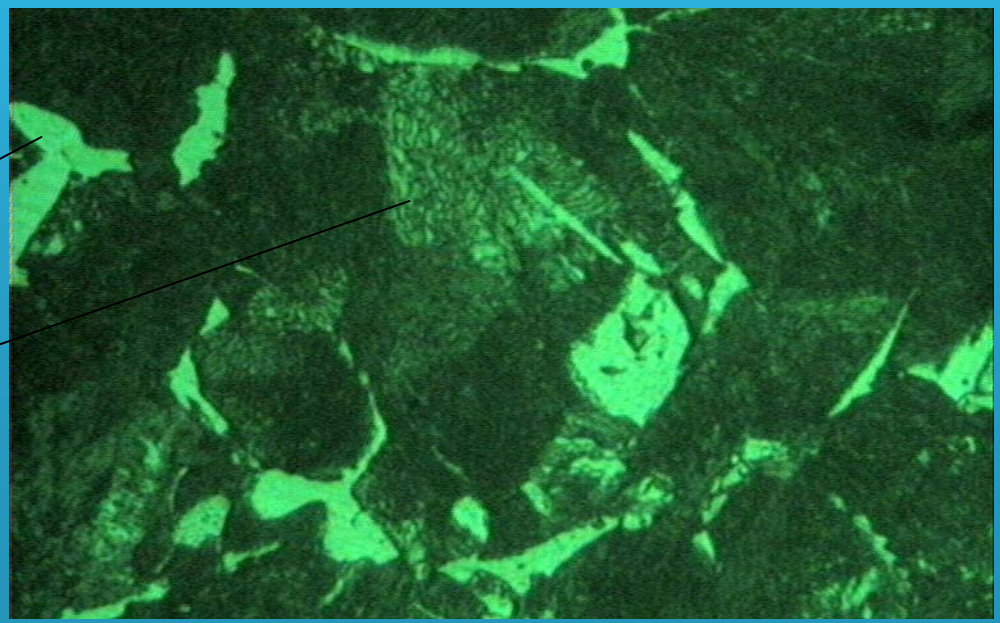
Effect of C content

0,45 % C

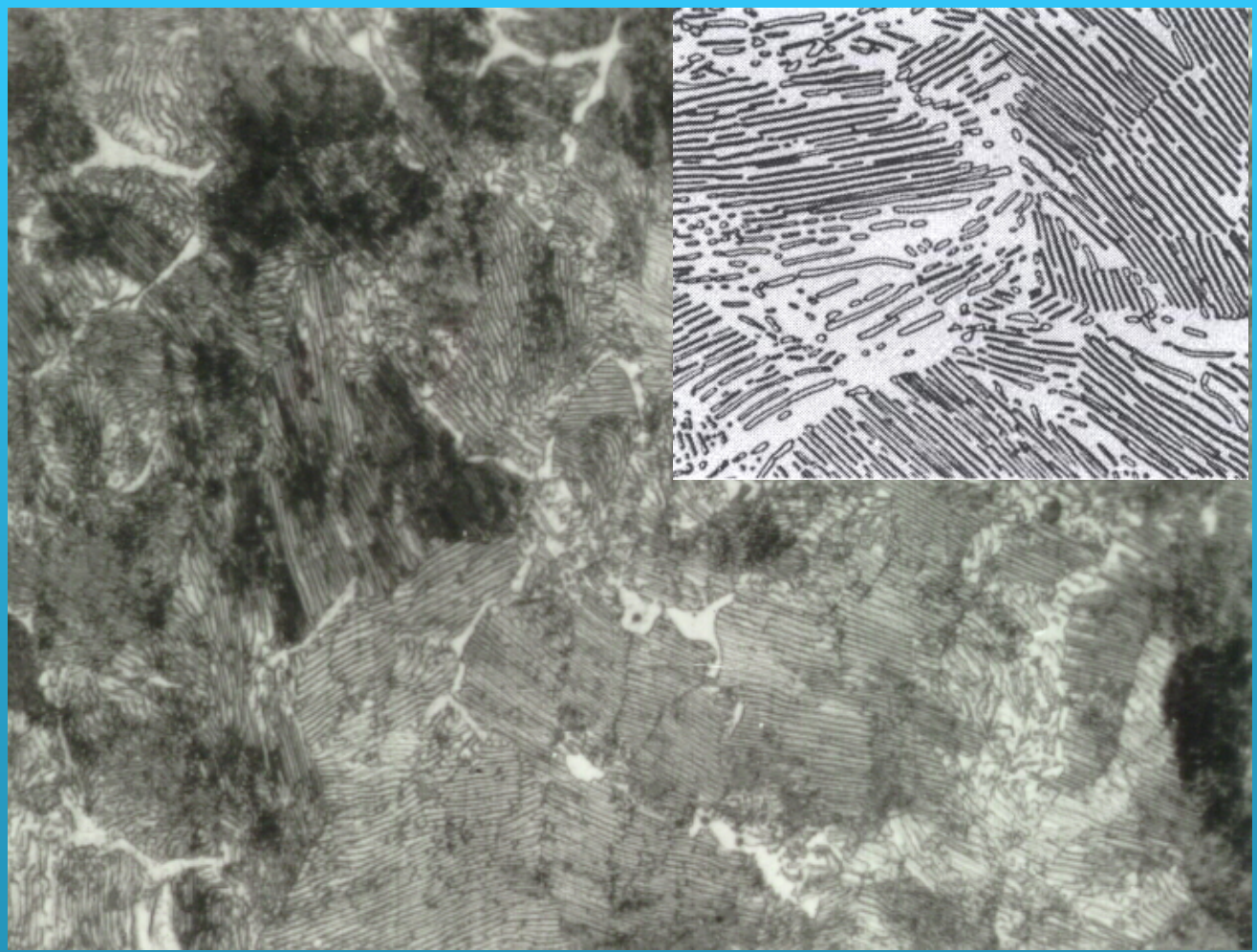
Microstructure

ferrite + pearlite





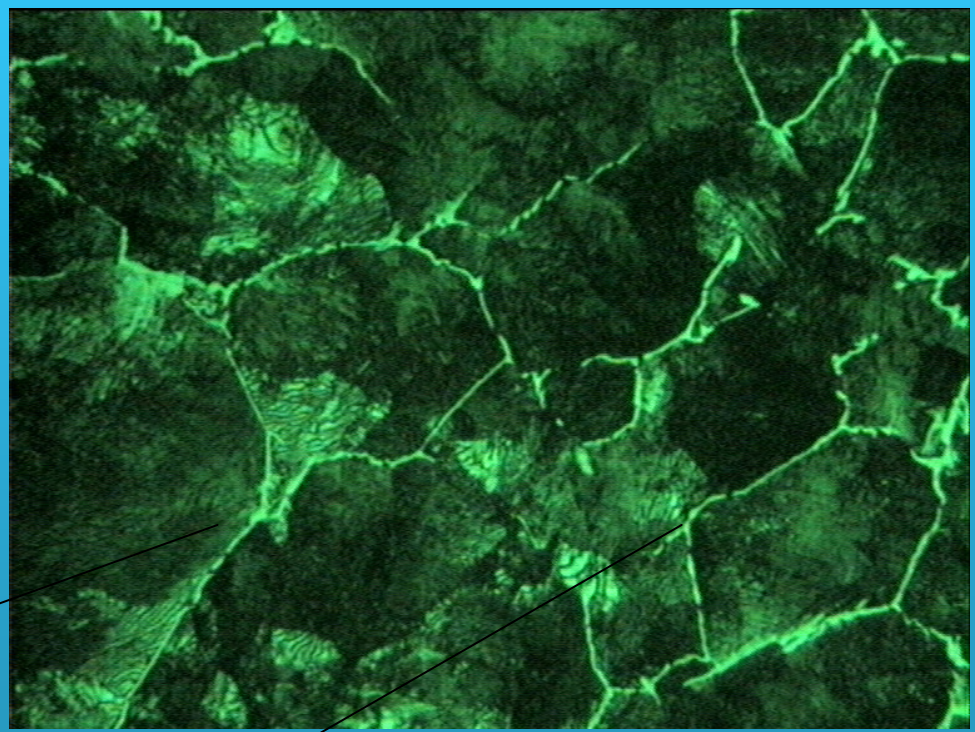
Pearlite: transformation of austenite to ferrite and cementite at 723ºC; C=0,8%



Hypereutectoid steel C ≈1,3 %

Microstructure

pearlite+ secondary cementite

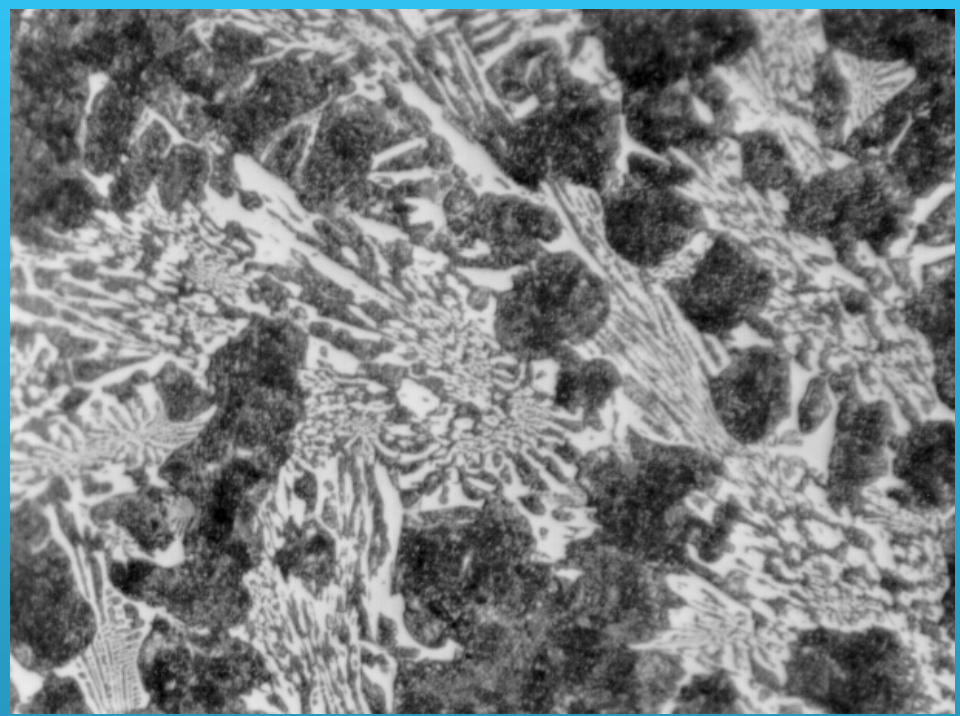


pearlite

Secondary cementite (net)

Ledeburite (eutectic)

At 1147 C°



Phases of ledeburite:

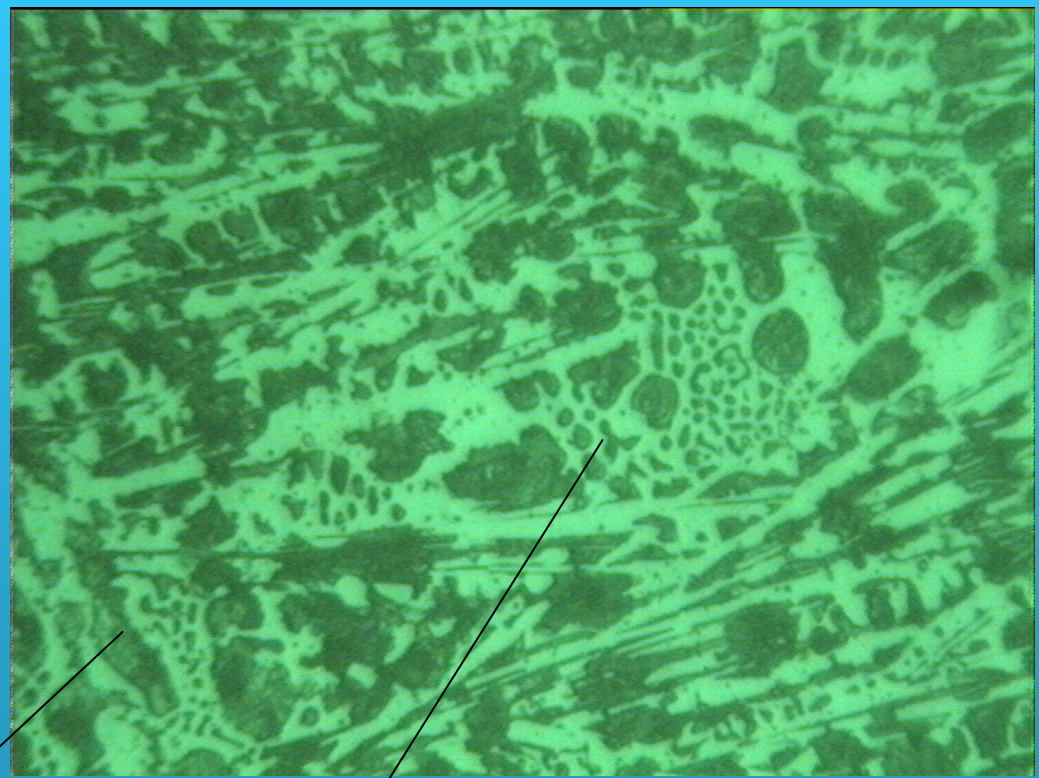
- **austenite**
- **iron-carbide**

Ledeburite

During cooling to room temperature:

austenite transforms to pearlite

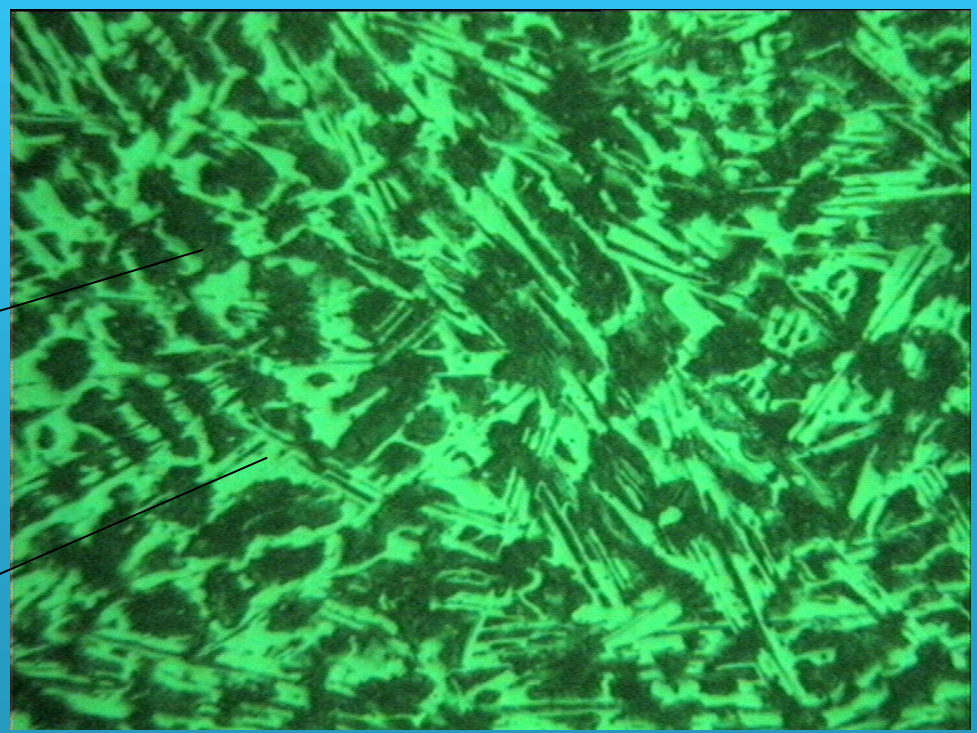
Hard, rigid, wear resistante



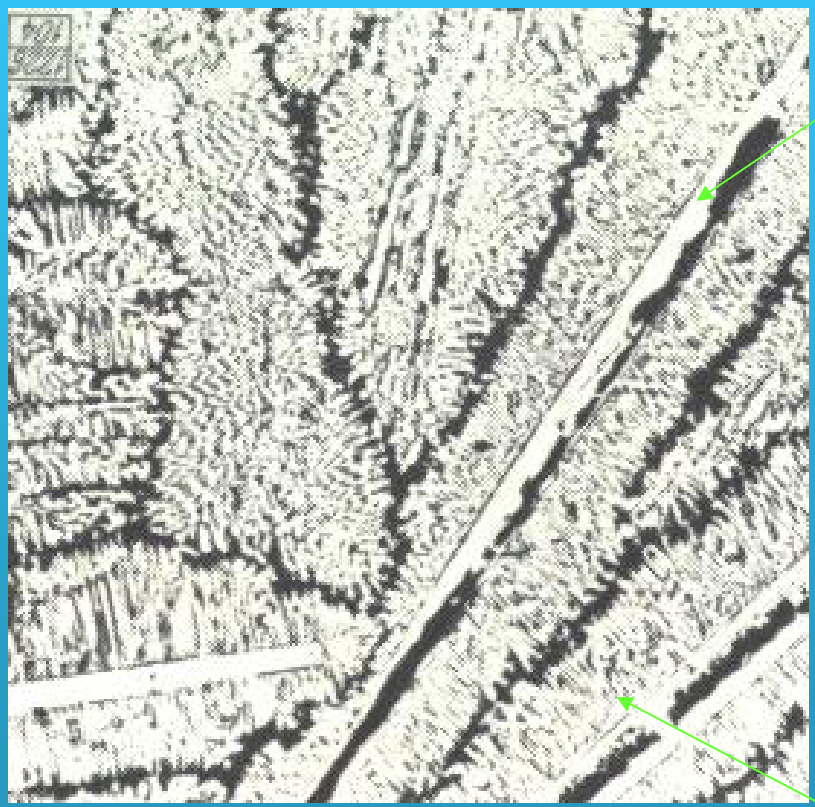
Hypoeutectic cast irons (white cast iron)

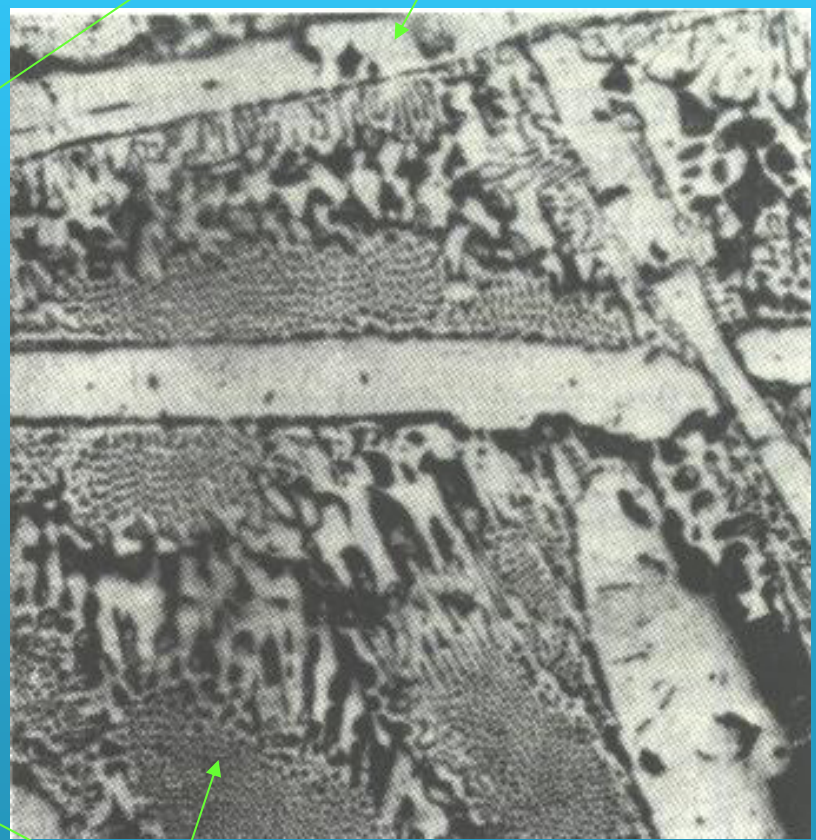
Microstructure:

pearlite + ledeburite + secondary cementite



Hypereutectic (white) cast irons



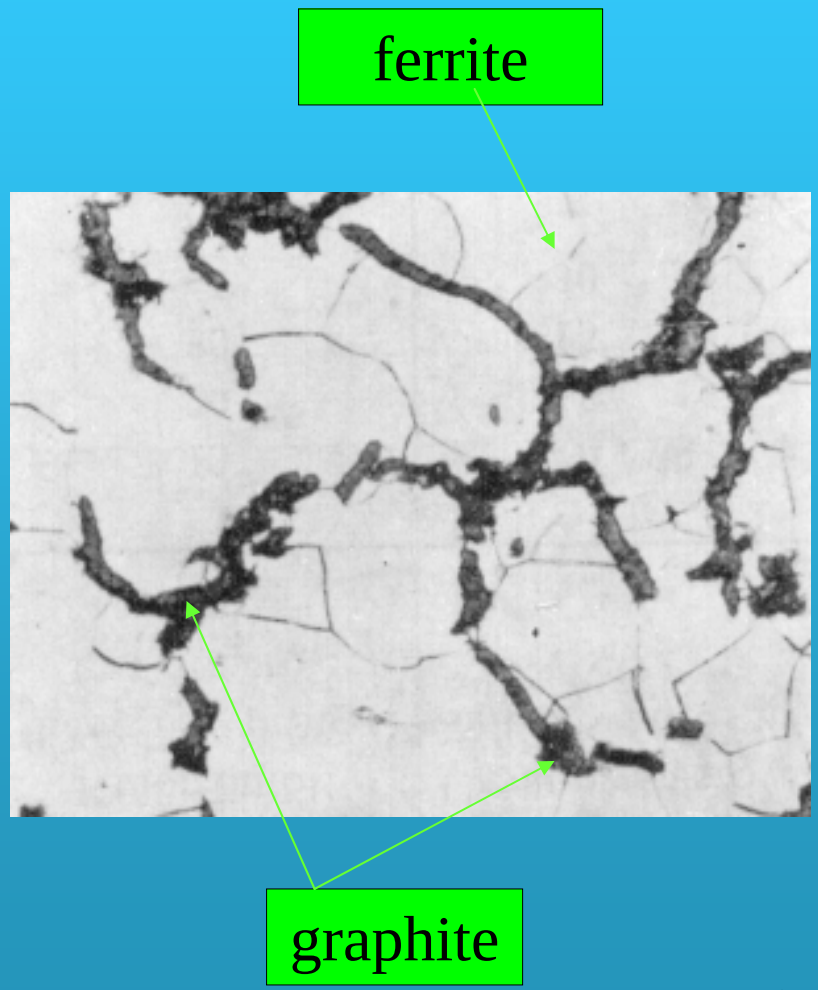


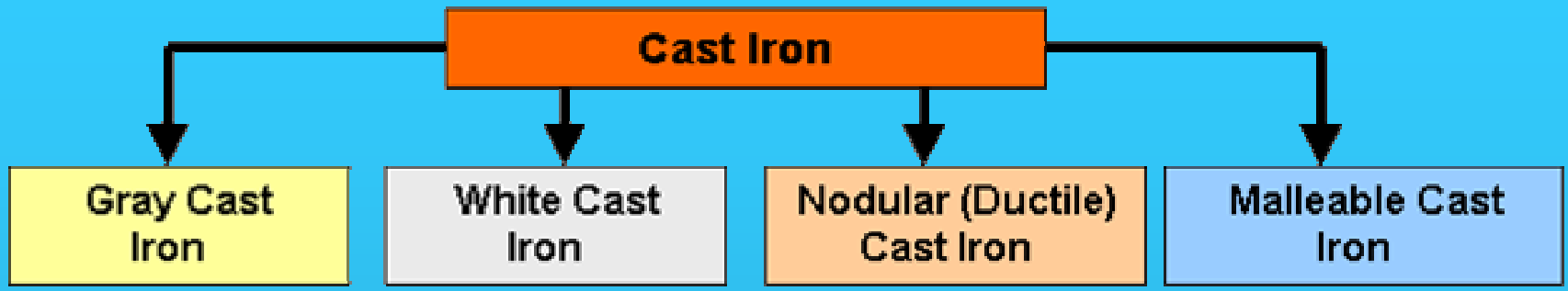
Hypoeutectic graphitic cast iron

- **graphitic eutectic**
- **secondary graphite**
- **graphitic eutectoid**

Structure at room temperature:

ferrite - graphite





Contains Si, Mn, P, S

Effect of wall thickness of the cast part (cooling rate)

Solidification and transformation

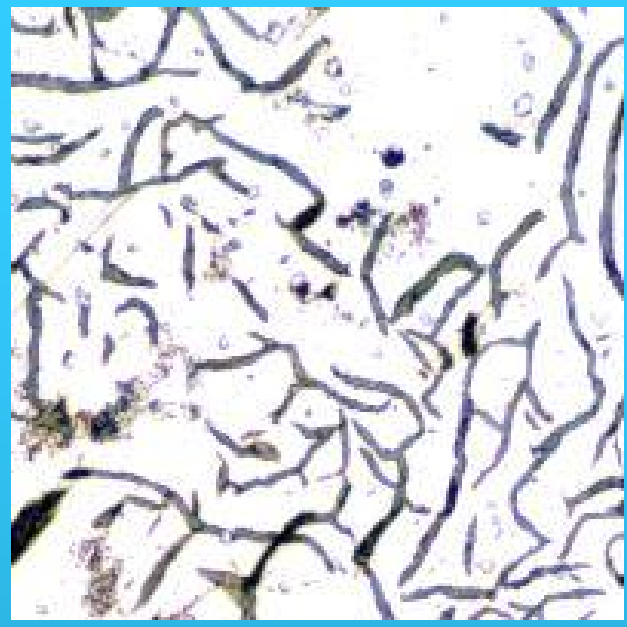
stable - metastable

Cast irons may often be used in place of steel at considerable cost savings. The design and production advantages of cast iron include:

- **Low tooling and production cost**
- **Good machinability**
- **Ability to cast into complex shapes**
- **Excellent wear resistance and high hardness (particularly white cats irons)**
- **High inherent damping capabilities**

The properties of the cast iron are affected by the following factors:

- **Chemical composition of the iron**
- **Rate of cooling of the casting in the mold (which depends on the section thickness in the casting)**
- **Type of graphite formed (if any)**

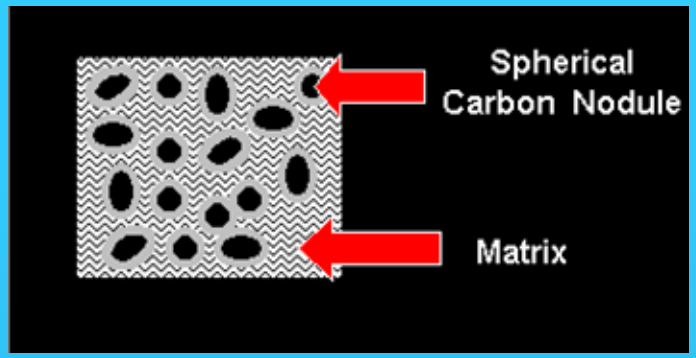


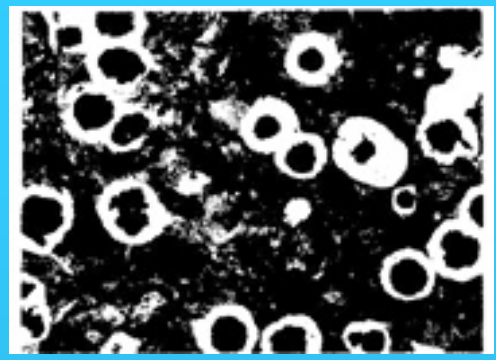
Advantages:

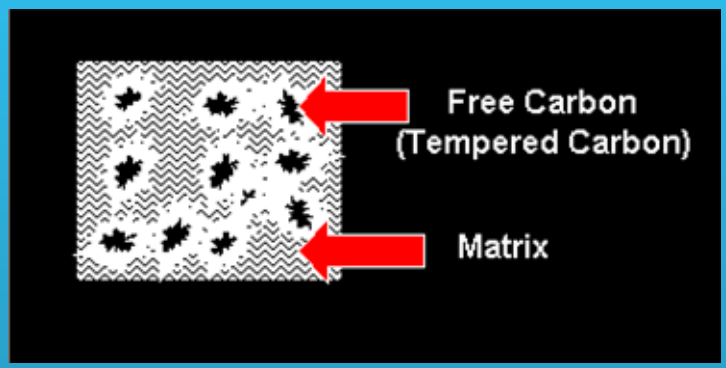
- **Graphite acts a s a chip breaker and a tool lubricant.**
- **Very high damping capacity.**
- **Good dry bearing qualities due to graphite.**
- **After formation of protective scales, it resists corrosion in many common engineering environments.**

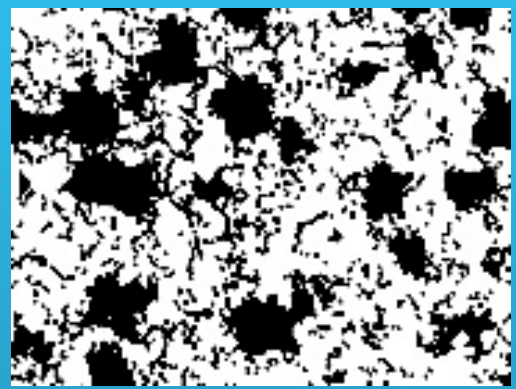
Disadvantages:

- **Brittle (low impact strength) which severely limits use for critical applications.**
- **Graphite acts as a void and reduces strength. Maximum recommended design stress is 1/4 of the ultimate tensile strength. Maximum fatigue loading limit is 1/3 of fatigue strength.**
- **Changes in section size will cause variations in machining characteristics due to variation in microstructure.**
- **Higher strength gray cast irons are more expensive to produce.**





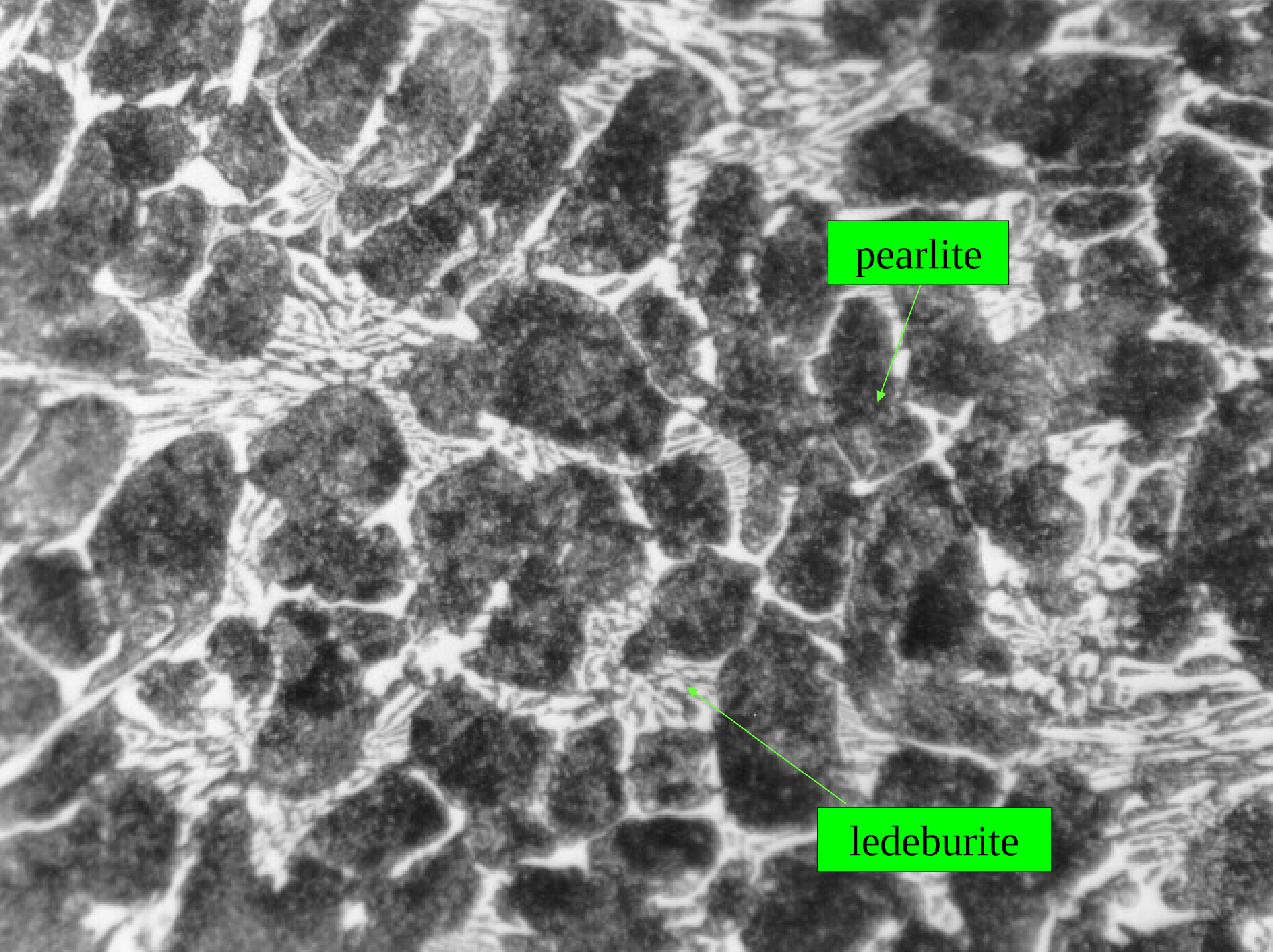


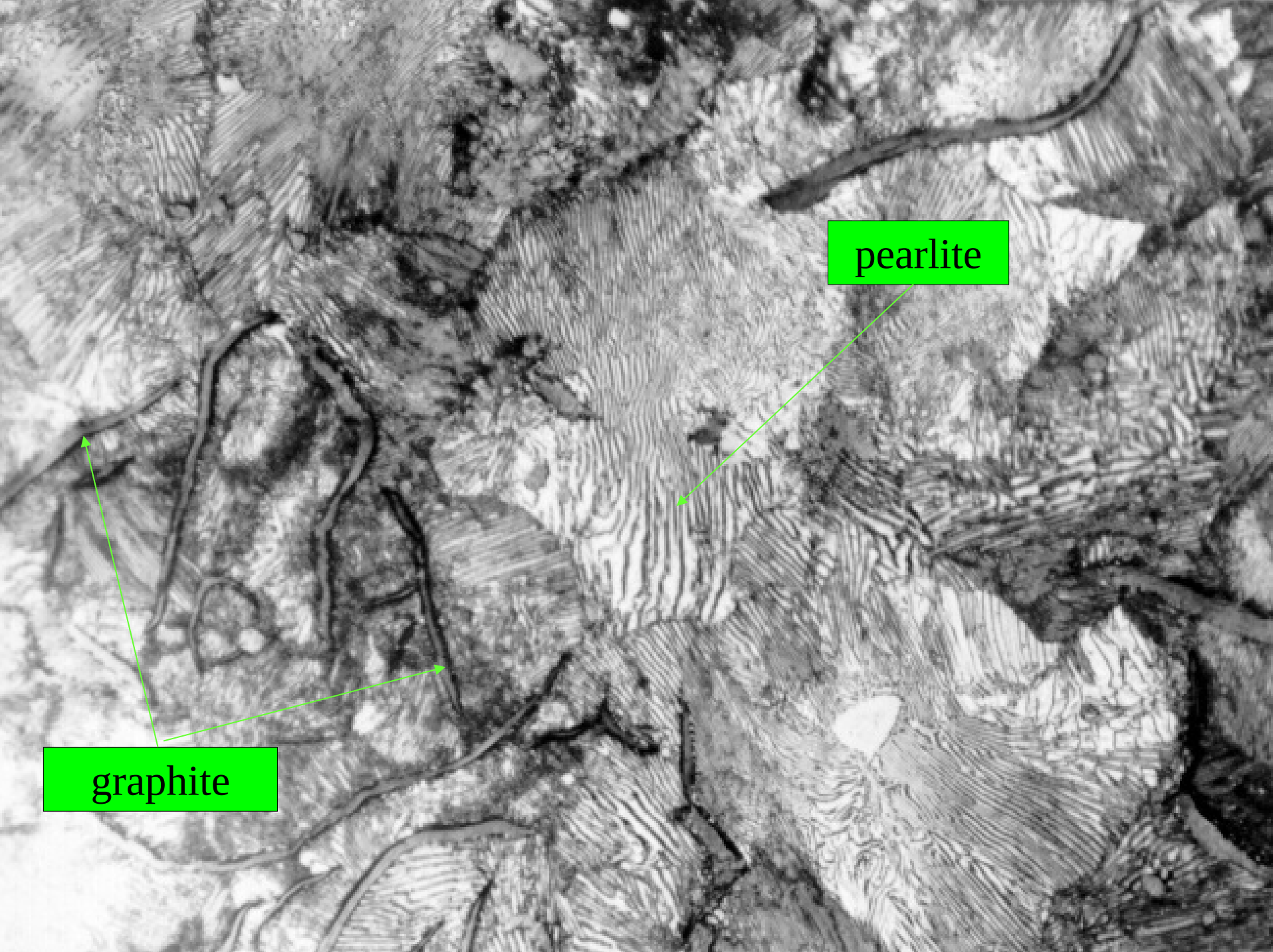


Ductile Cast Iron

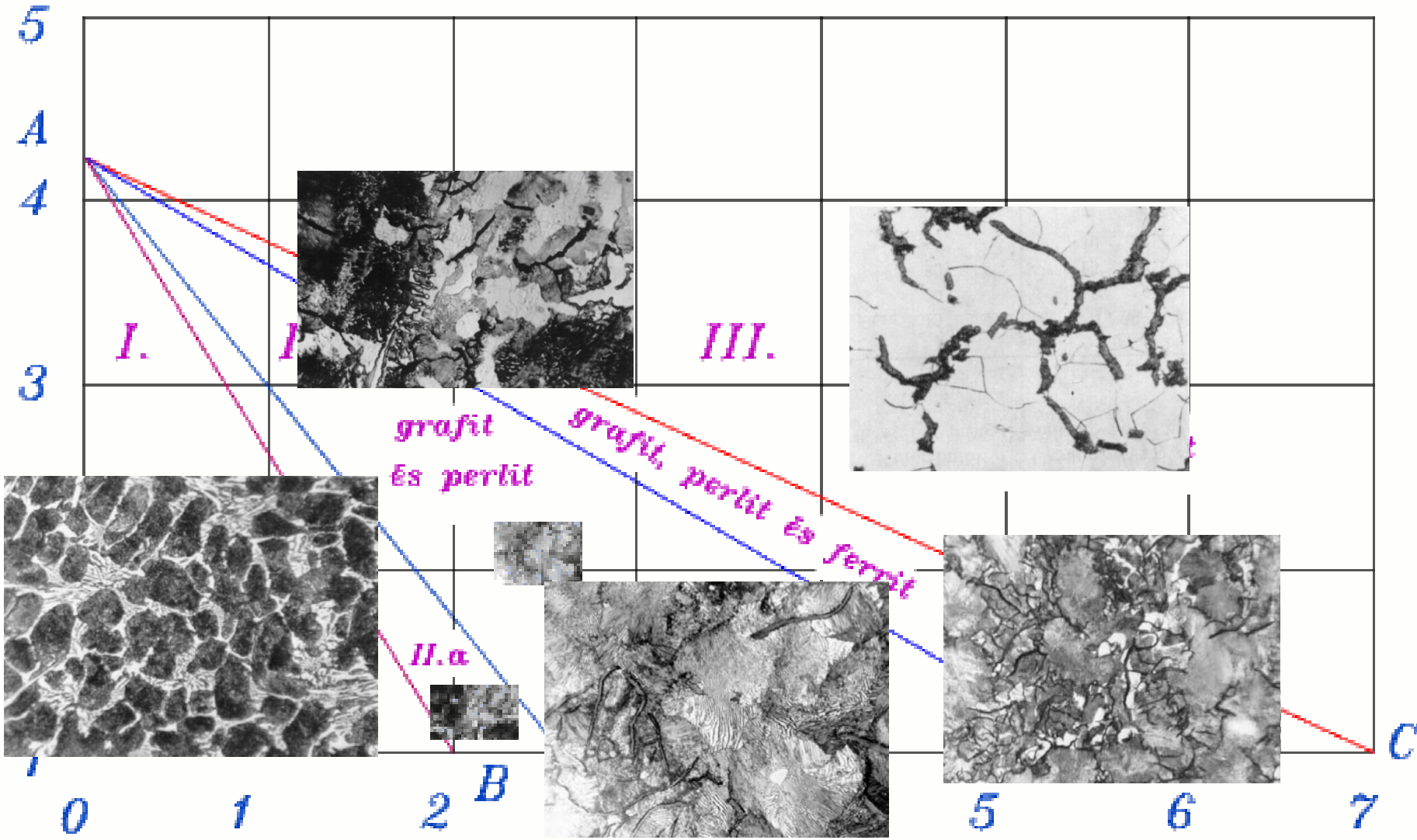
Nodular Cast Iron

Malleable Cast Iron


pearlite
ledeburite


pearlite
graphite

Maurer diagram



Carbon, wt. %

Silicon, wt. %

Greiner - Klingenstein diagram