Eutectoids with cementite as major constituent in Fe-C-M

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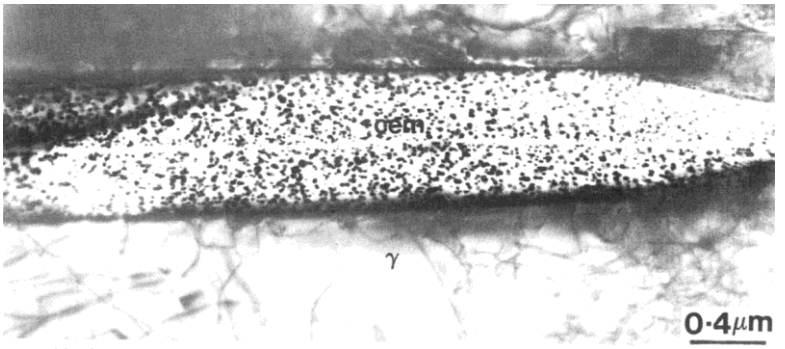
Effect of third element to hypereutectoid Fe-C alloys

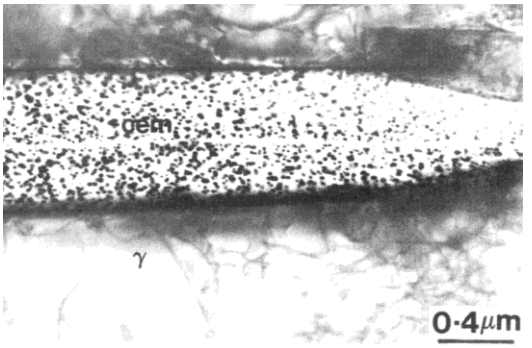
- Addition of a third element to hypereutectoid Fe-C alloys may cause inclusions of a minor constituent in the precipitate of cementite from austenite.

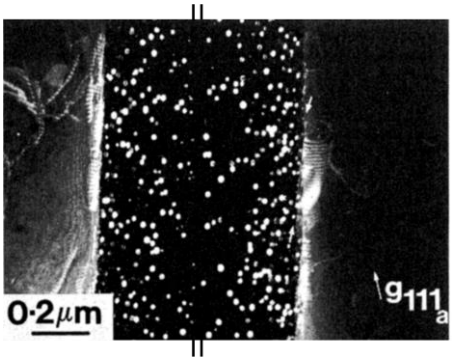


Khalid et al, 1990

Cementite plate with Cu-rich particles

- Khalid et al explained it as a result of precipitation from supersaturated cementite.
- An alternative explanation could be that it forms by cooperative growth, i.e. as a eutectoid transformations.





Fe-0.83C-9.7 Mn-2.57Cu, 500 C Khalid et al, 1990

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How can we explain if it can take place as a eutectoid transformation or not?

It can be explained by:

- a graphical method based on the three-phase triangle in combination with a relation between the slopes of tie-lines and the isoactivity lines for carbon in austenite.
- using an isothermal and isobaric phase diagram with an axis for the carbon activity.

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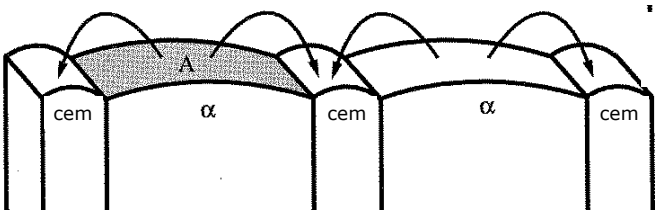
Similarities between eutectoid transformations in binary and ternary systems

Binary system, Fe-C

- Short-range diffusion of carbon between α and cem.
- Long-range flow of heat.
- The growth rate is governed by carbon diffusion.
- Austenite will be heated up – divergent eutectoid.
- Invariant under constant pressure.

Ternary system, Fe-C-M

- Short-range diffusion of alloying element M between α and cem.
- Long-range diffusion of carbon.
- The growth rate is governed by M diffusion.
- Austenite will be depleated in carbon – divergent eutectoid.
- Invariant under constant pressure and temperature.



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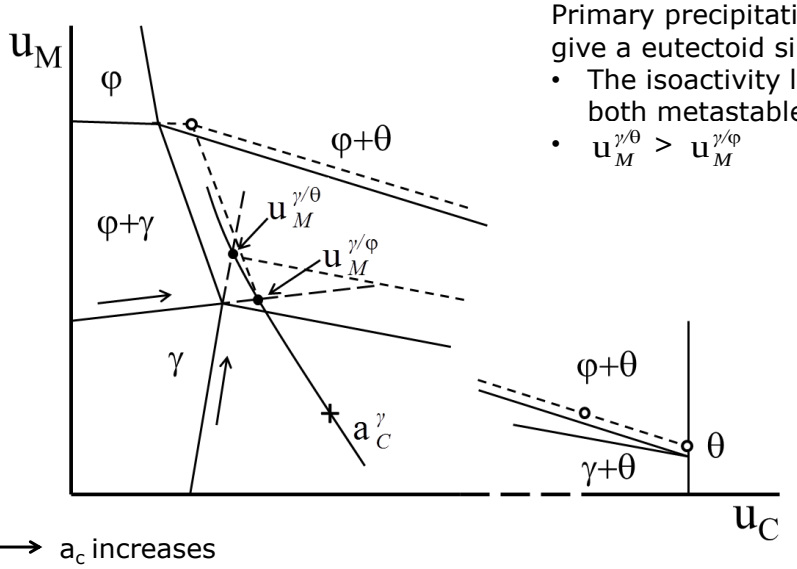
Schematic isothermal section, case 1 could represent Fe–C-Cu, Al, Si



Primary precipitation of θ can give a eutectoid since

- The isoactivity line intersects both metastable extensions.
- $u_M^{\gamma/\theta} > u_M^{\gamma/\varphi}$

→ a_c increases

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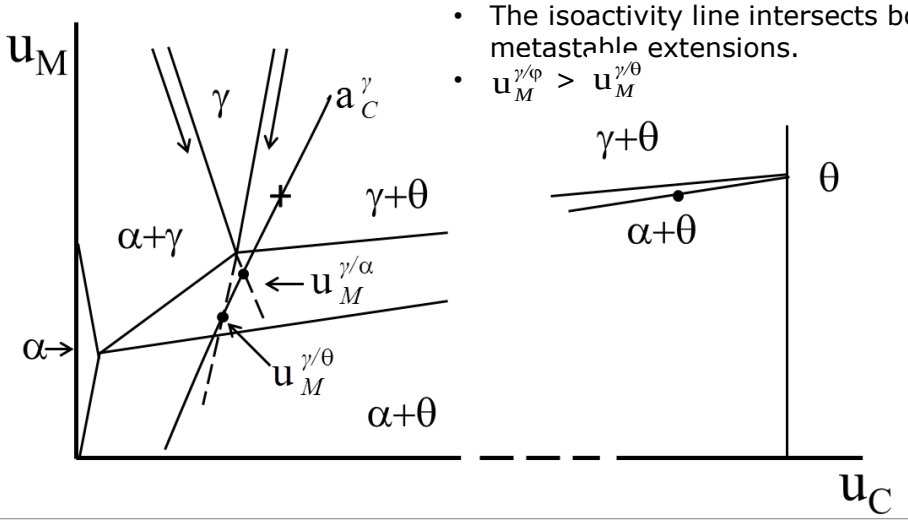
Schematic isothermal section, case 2 could represent Fe–C-Mn

Primary precipitation of θ can give a eutectoid since

- The isoactivity line intersects both metastable extensions.
- $u_M^{\gamma/\varphi} > u_M^{\gamma/\theta}$



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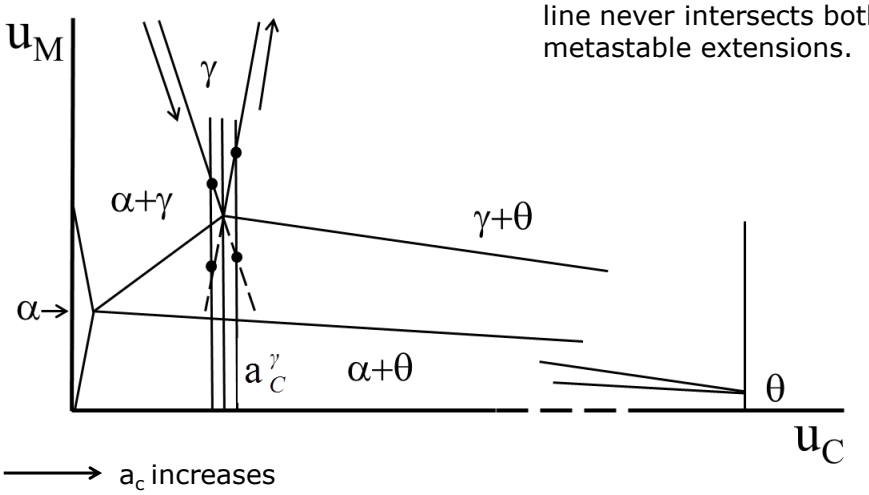
Schematic isothermal section, case 3 could represent Fe–C-Ni

Primary precipitation of θ cannot give a eutectoid since the isoactivity line never intersects both metastable extensions.



⟶ a_c increases

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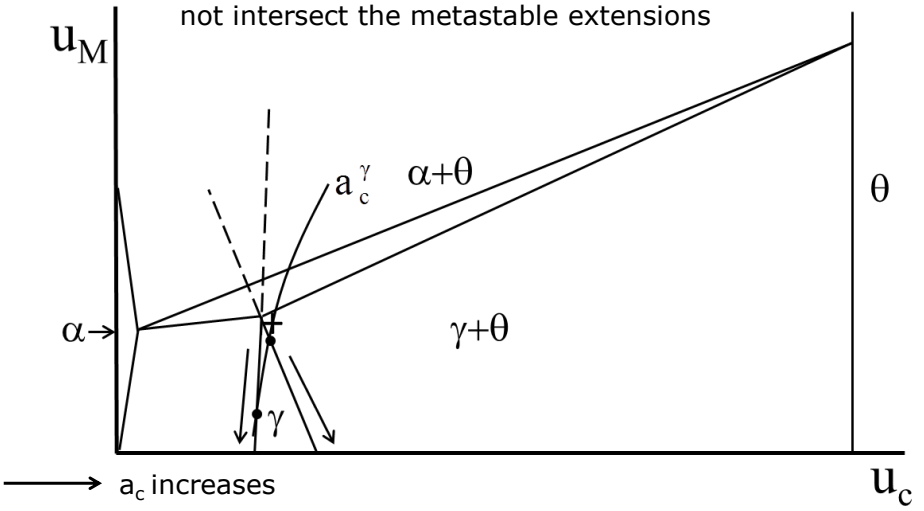
Schematic isothermal section, case 4 could represent Fe–C-Cr

Primary precipitation of θ cannot give a eutectoid since the isoactivity line does not intersect the metastable extensions



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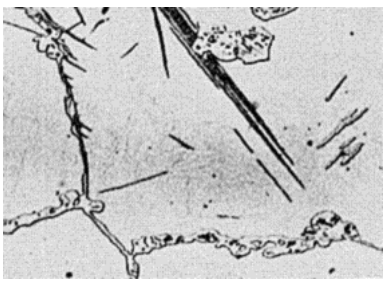
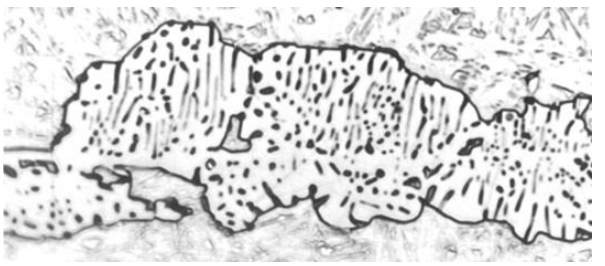
Porous cementite in Fe-C-Si



High carbon steel 0.92% Si, 800 C

Hultgren and Edström, 1937



Carbon steel 0.25% Si, 728 C

Fridberg and Hillert, 1970

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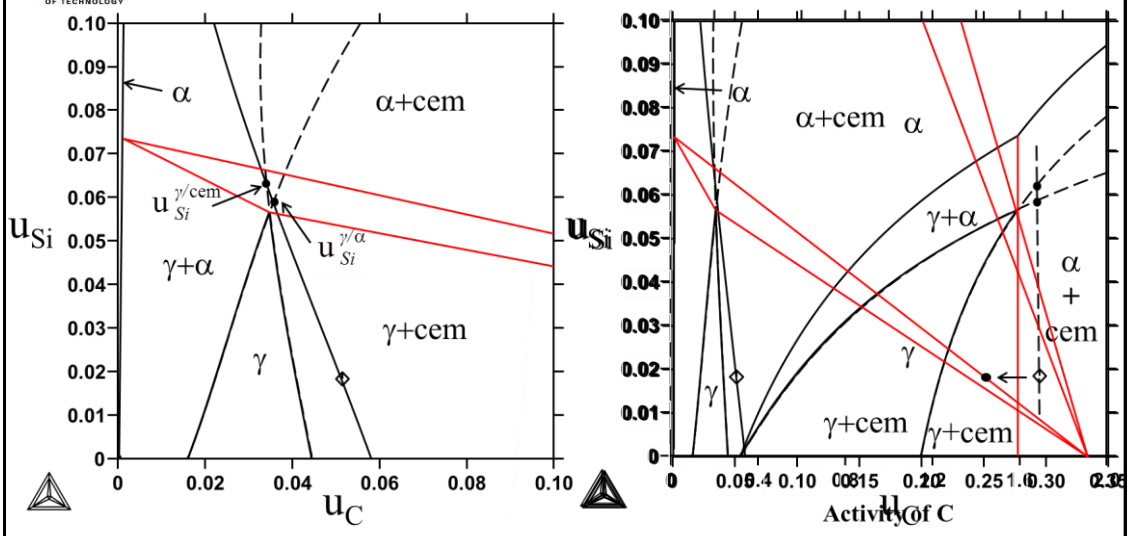
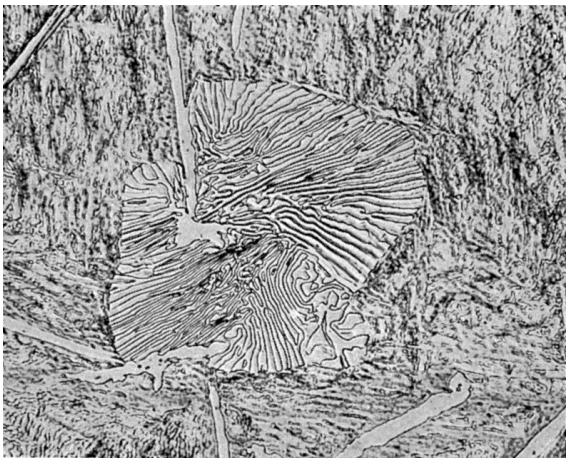
Fe-C-Si



- Can be explained by a eutectoid transformation.

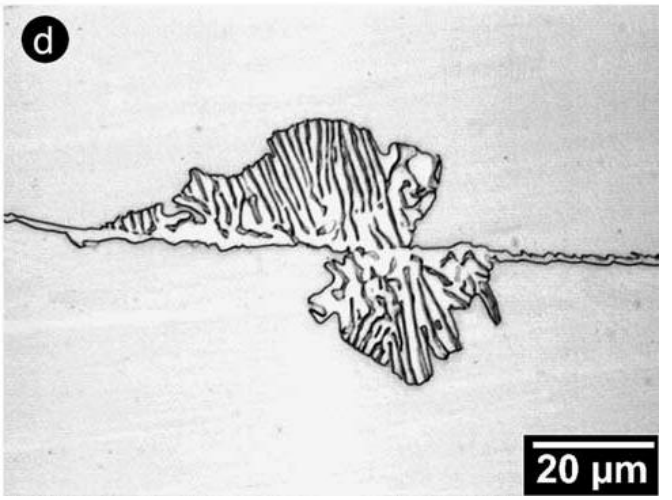
Divergent pearlite in Fe-C-Mn



Fe-1C-5Mn, 680C

Cahn and Hagel, 1962

Pearlite formation above Ae1



Fe-0.85C-11.56Mn, 670C

Hutchinson and Shiflet, 2004

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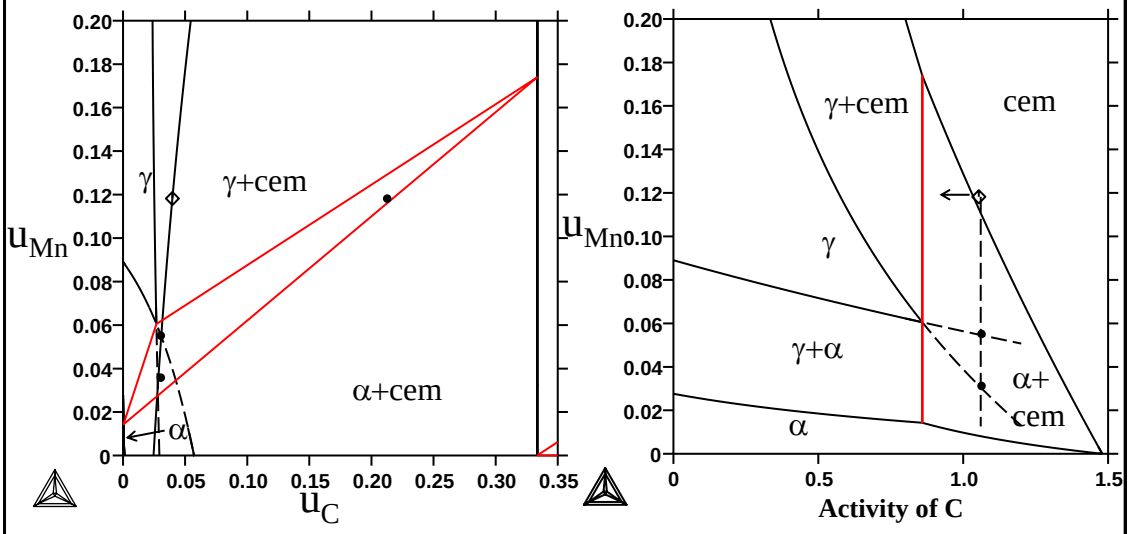
Fe-C-Mn



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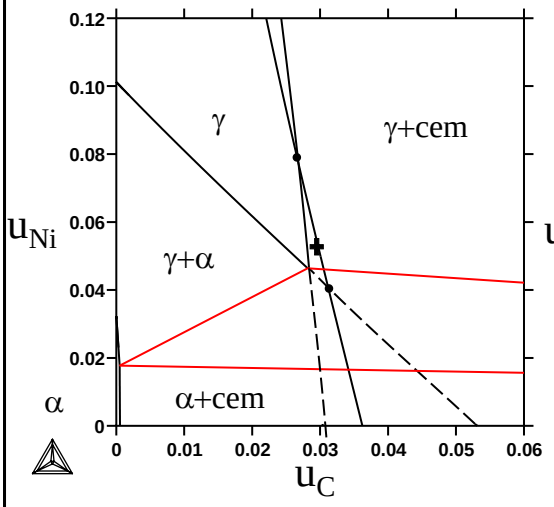
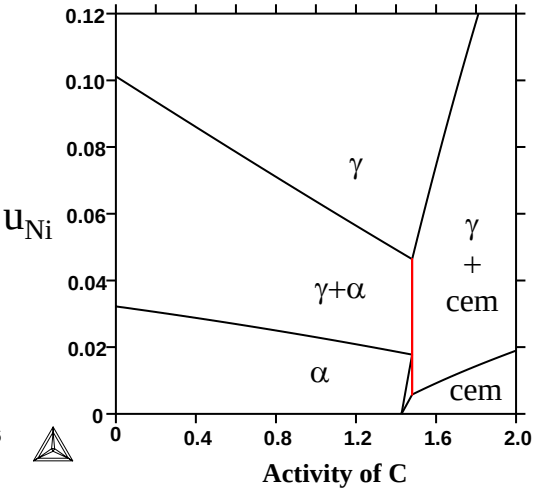
Fe-C-Ni

- Eutectoid structure with cementite as major constituent has not been observed.
- Obvious from the phase diagram





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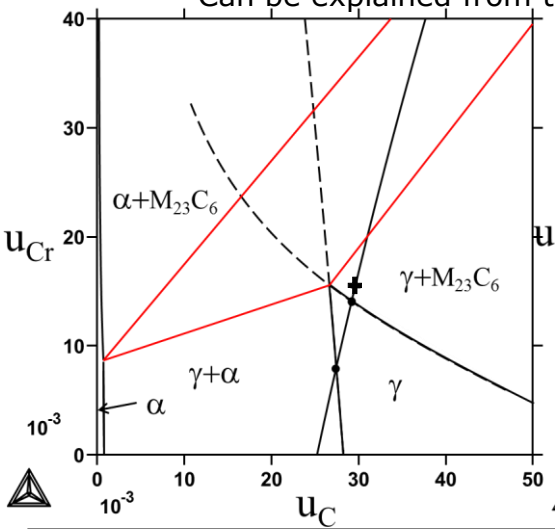
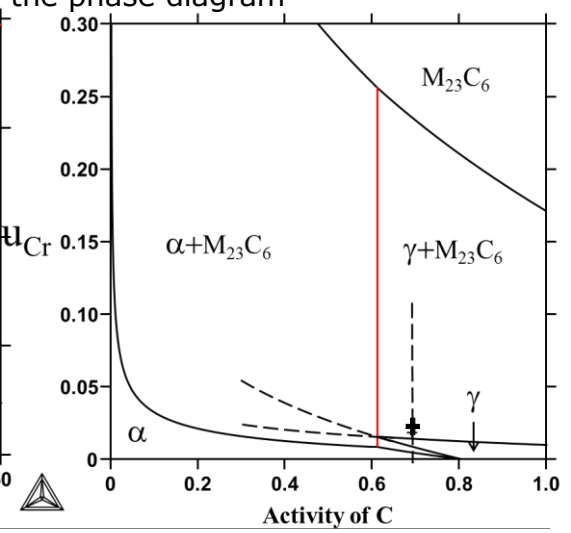
Fe-C-Cr

- Eutectoid structure with cementite as major constituent has not been observed.
- Can be explained from the phase diagram





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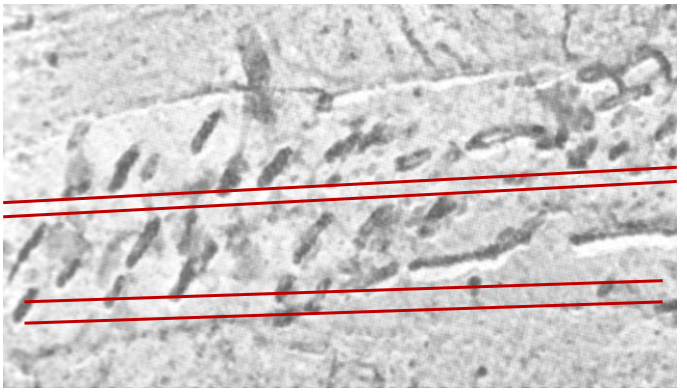
Comparison with bainite



Pickering, 1960

Bainite formed in Fe-0.69C steel

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Conclusions

It has been demonstrated that experimental results of a two-phase mixture with cementite as the major phase can be explained as a eutectoid transformation.

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Thanks for your attention!

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