Ductile Iron Society T&O Meeting

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UNDERSTANDING THE FORMATION OF DROSS IN DUCTILE IRON CASTINGS

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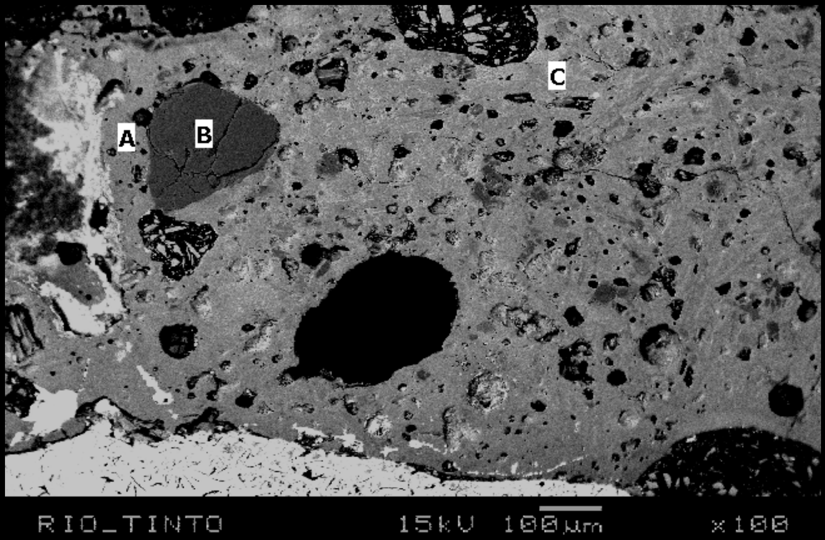
DEFINITIONS:

- Dross, slag & sand inclusions are the three major non-metallic inclusions found in DI;
- Drosses are endogenous while slag and sand inclusions are exogenous;
- Drosses have a filamentary aspect while slag inclusions exhibit a blocky appearance;
- Magnesium silicate filaments (drosses) are forming within the iron during pouring (in the stream, in the pouring basin, in the gating system or during the first filling of the mold cavity),whereas slag is mainly originating from the magnesium treatment and the residues from the furnace and the ladle.

EXAMPLES:

Slag and Sand Defects:



Slag & Sand Inclusions:

A= 54%SiO_2, 17%MgO,18%CaO;

B= SiO_2 100% sand;

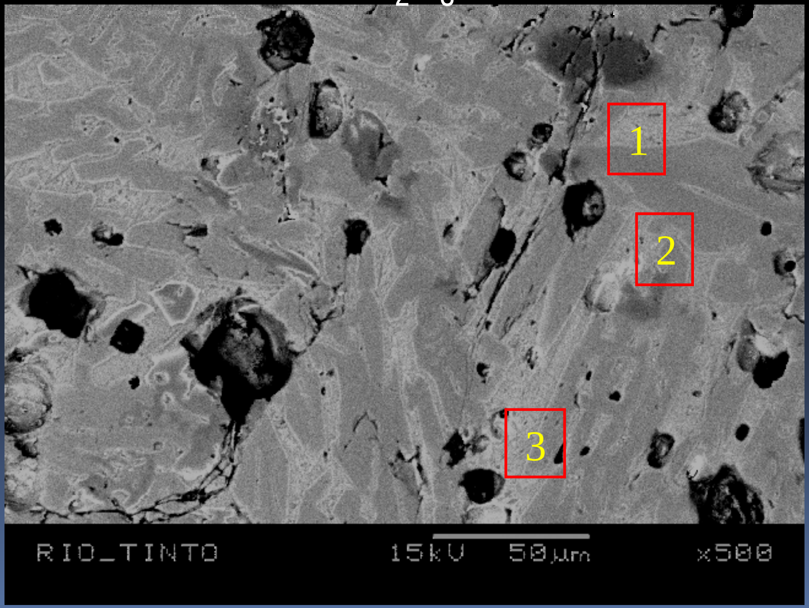
C= →

« C » area at high magnification

1= 44%SiO_2, 52%MgO;

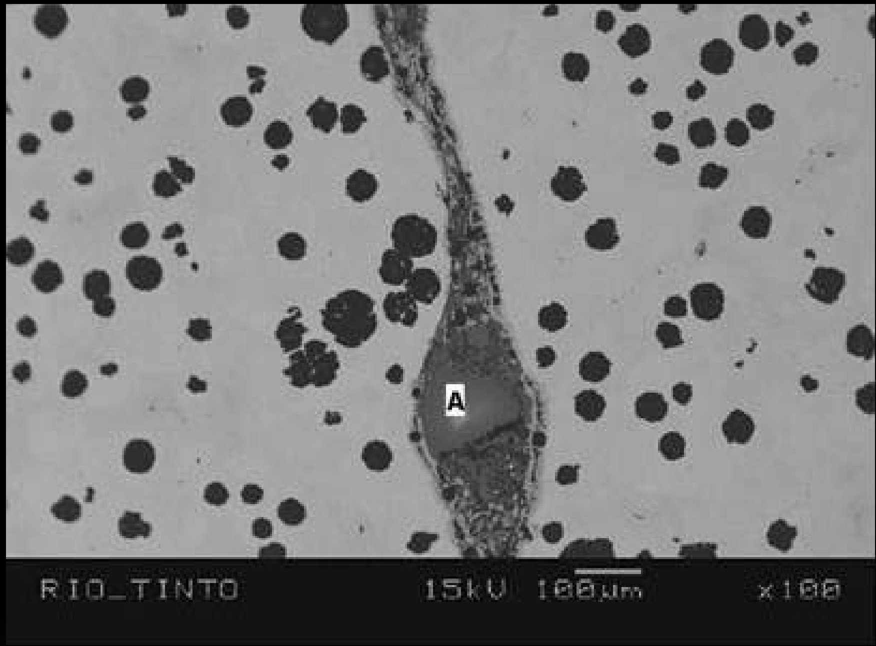
2= 53%SiO_2 , 18%CaO, 16%MgO;

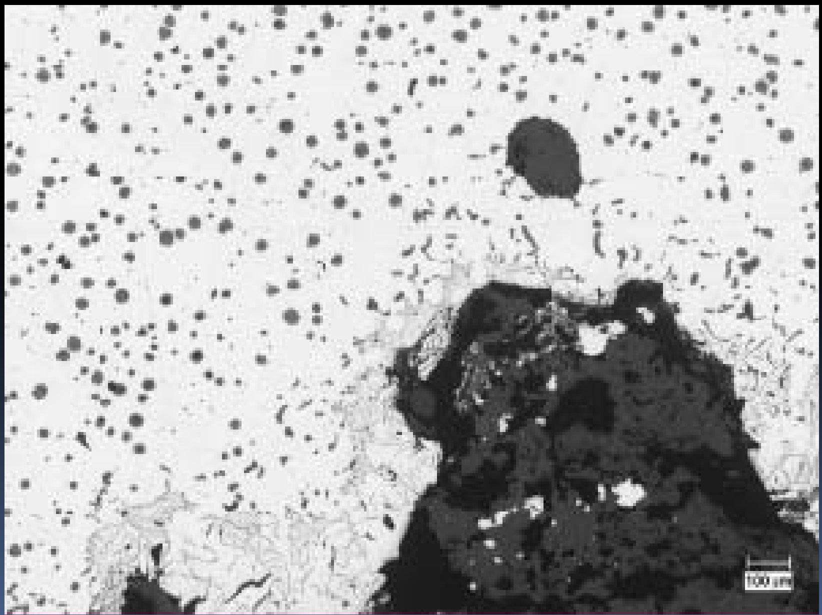
3 = 54%SiO2, 18%Al_2O_3, 10% CaO, 15%FeO



EXAMPLES:

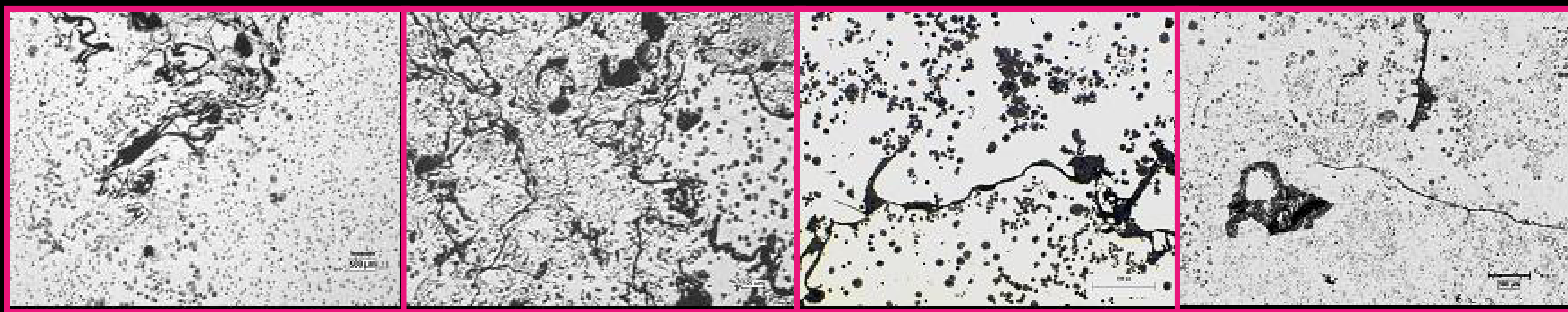
Slag and Sand Defects:





EXAMPLES:

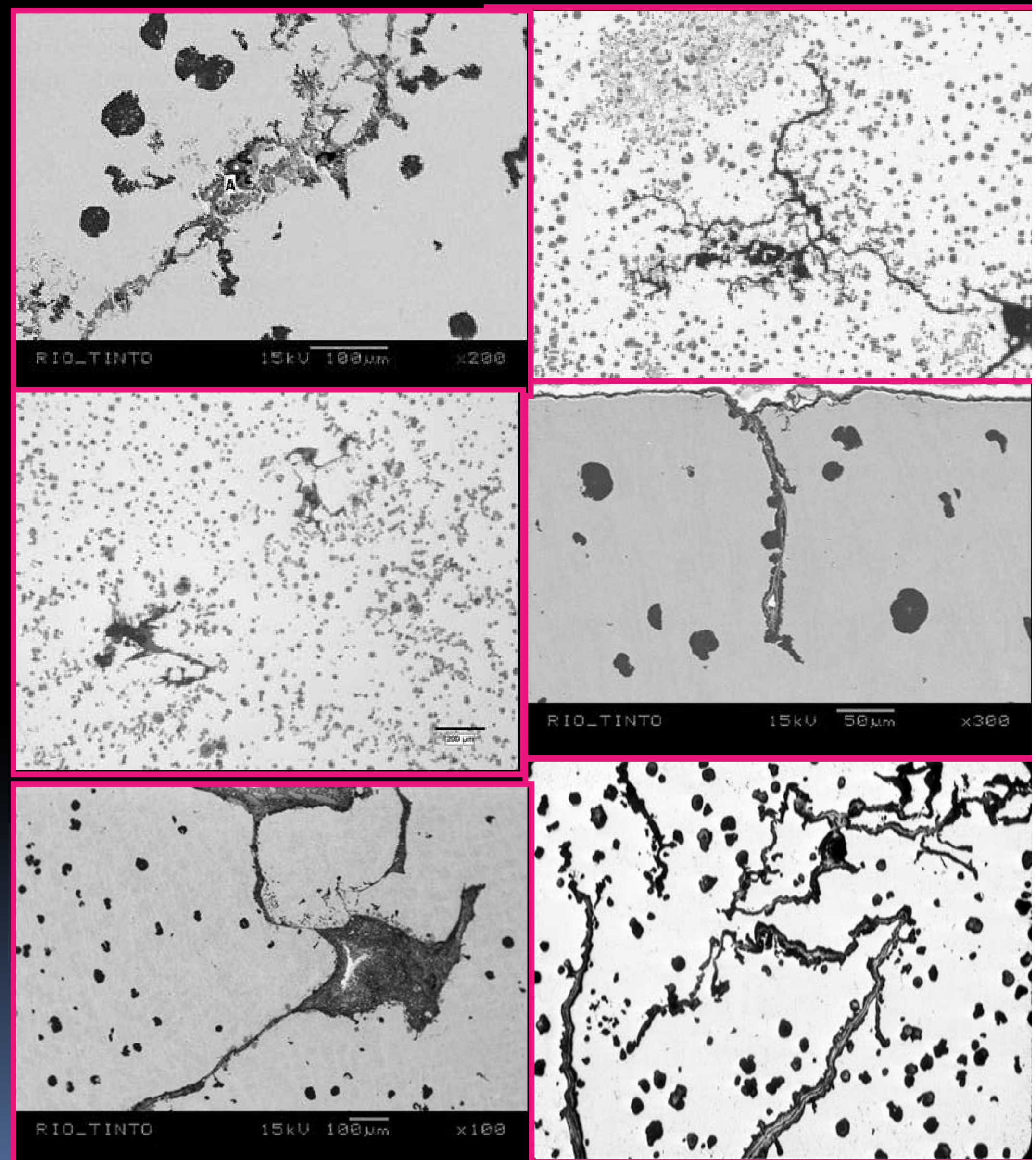
Dross Defects:



Analysis no.	1	2	3	4	5	6
MgO	25%	14	16	48	40	24
SiO_2	56%	55	62	44	36	33
Al_2O_3	7%	5	8	5	6	1
CaO	0.5	-	-	-	-	-
MnO	5	23	11	-	3	8
FeO	4	3	2	2	16	31

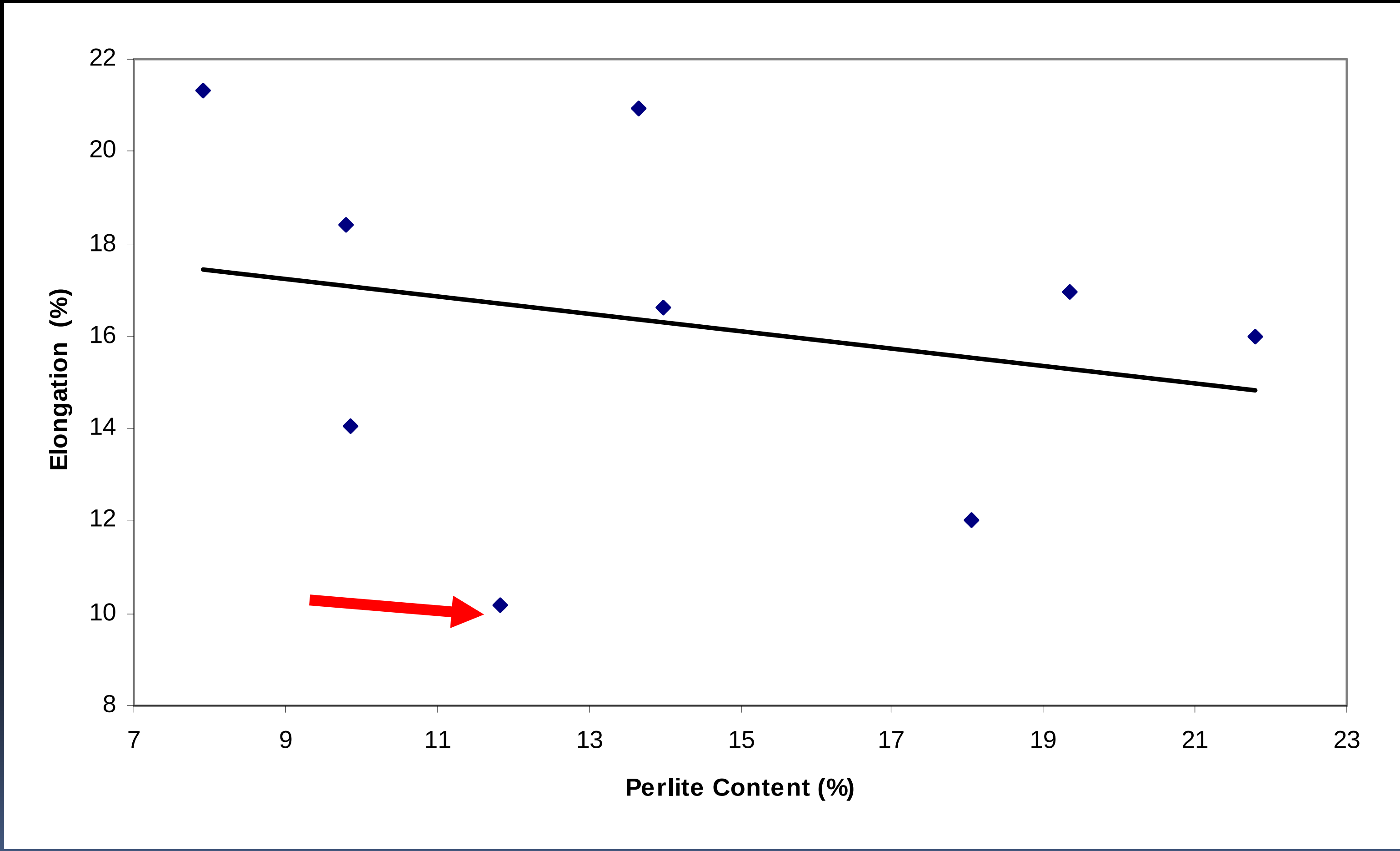
EXAMPLES:

Dross Defects:



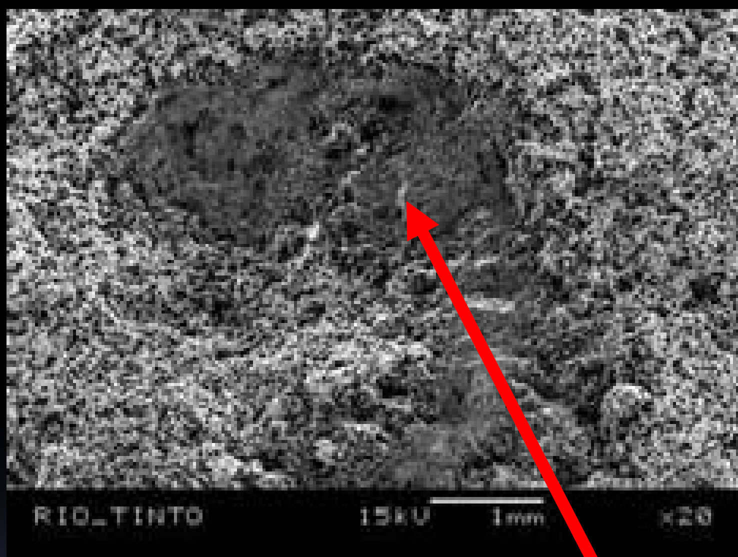
EFFECT on MECHANICAL PROPERTIES:

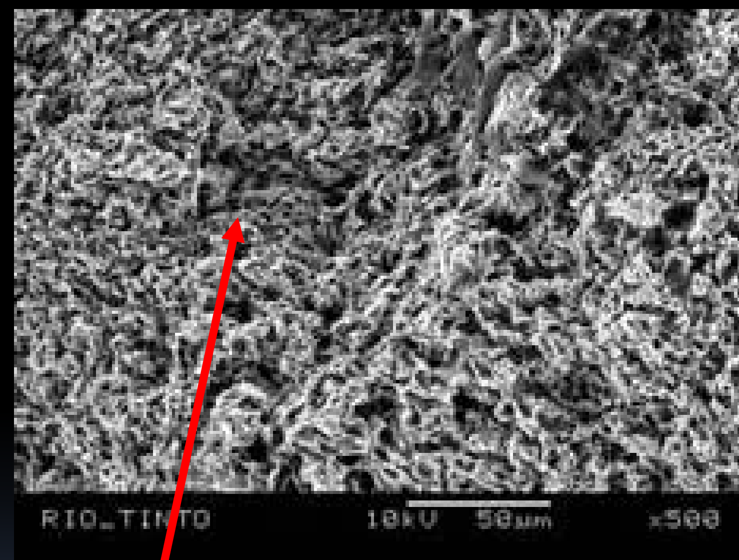
Ductility



EFFECT on MECHANICAL PROPERTIES:

Low Ductility: Dross on Fracture Surface

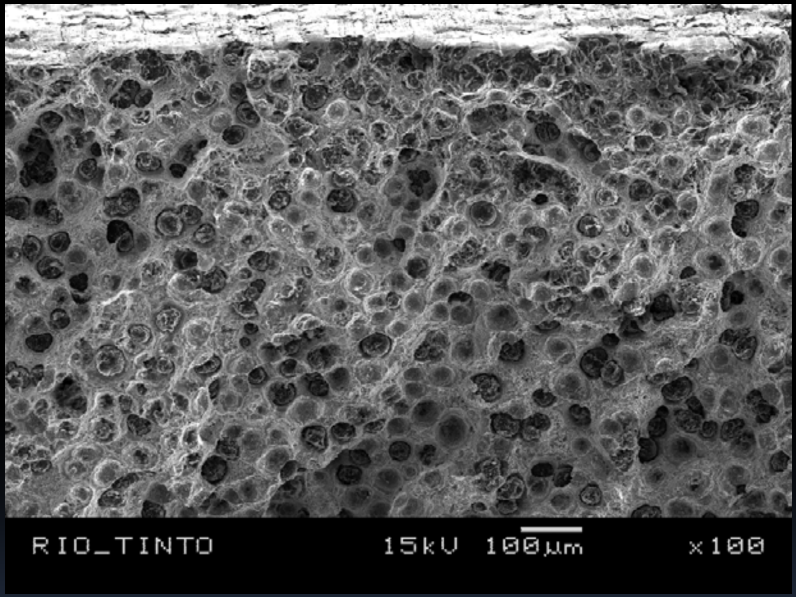


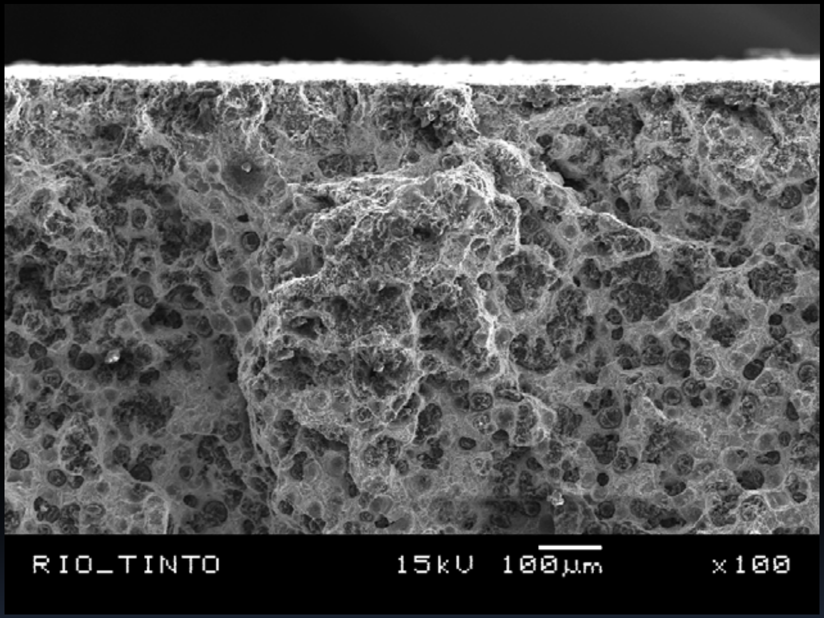


Dross

EFFECT on MECHANICAL PROPERTIES:

Impact Energy: Dross on Fracture Surface





No Dross: 114 lb-ft

With Dross: 52 lb-ft

ADI: un-notched Charpy specimens

EFFECT on MECHANICAL PROPERTIES:

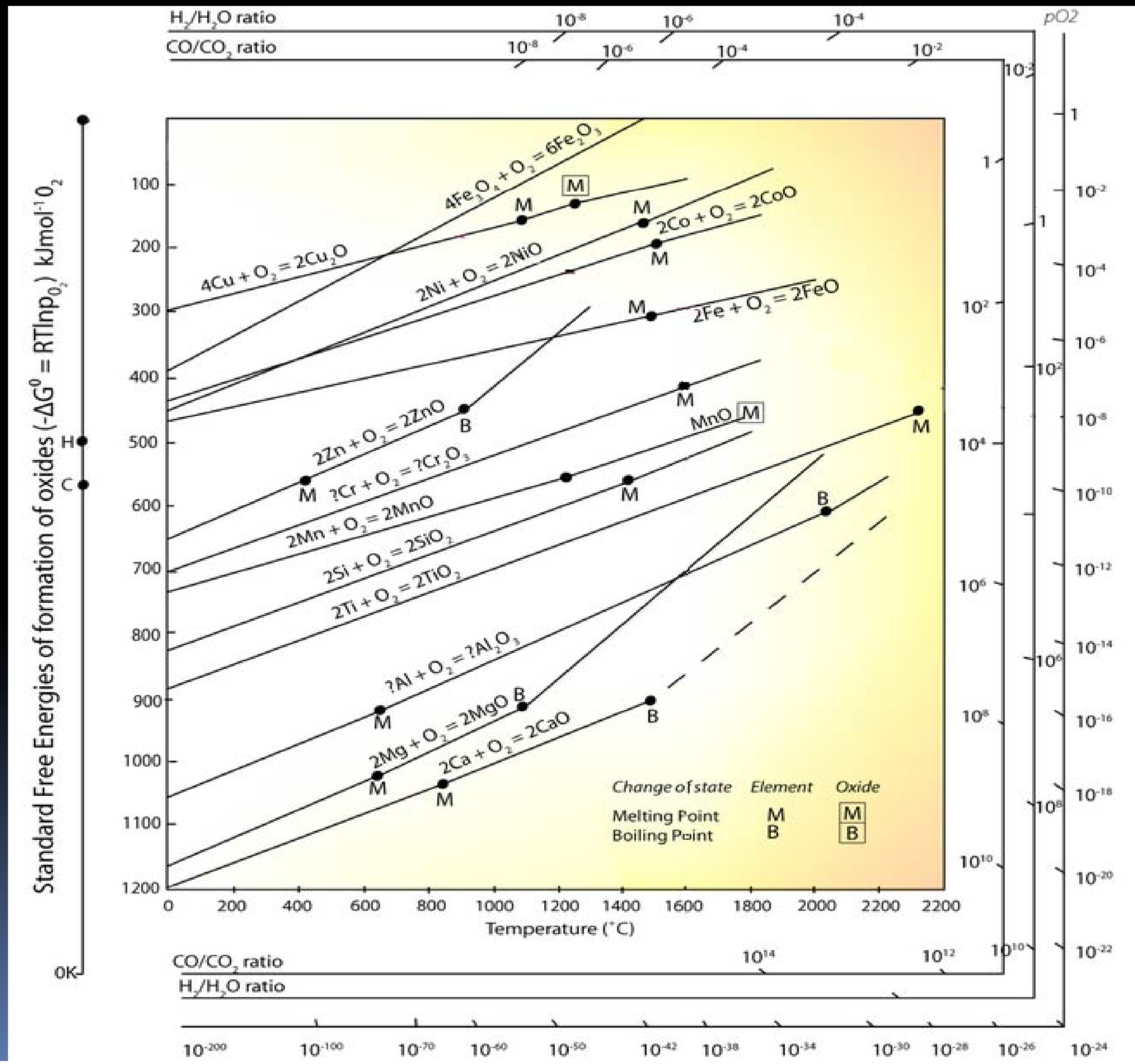
Fatigue Strength:

Defect	Rel. Fatigue Endurance
None	1.00
Dross	0,54
Micro shrinkage.	0,73
Macro shrinkage	0,50
Chunk graph.	0,75
Anomalies	0,83

(Frauenhofer Institute / Refstie & Skaland – Vesta Group)

FORMATION, EXPLANATION & SIMULATION:

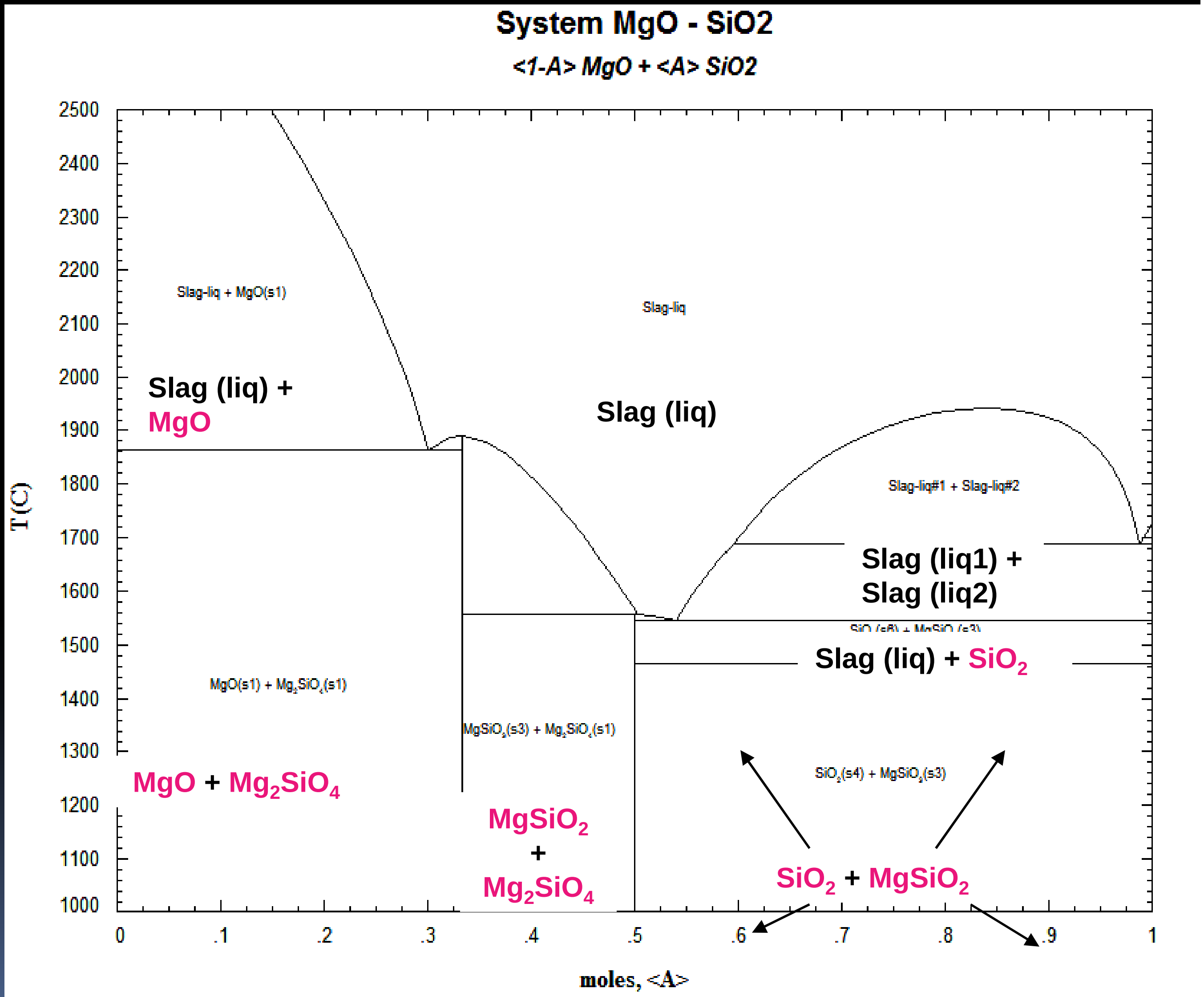
Ellingham diagram:



FORMATION, EXPLANATION & SIMULATION:

Binary Phase Diagram

$MgO – SiO_2$



FORMATION, EXPLANATION & SIMULATION:

✓Thermodynamic simulations were carried out to determine the conditions for dross formation

✓General Parameters:

- %S : 0,010 & 0,020;
- %Si: 2,0 & 2,5;
- %Mg: 0,04 – 0,06%;
- Temp.: 1300 to 1500C;
- Oxygen: 10 to 1000 ppm.

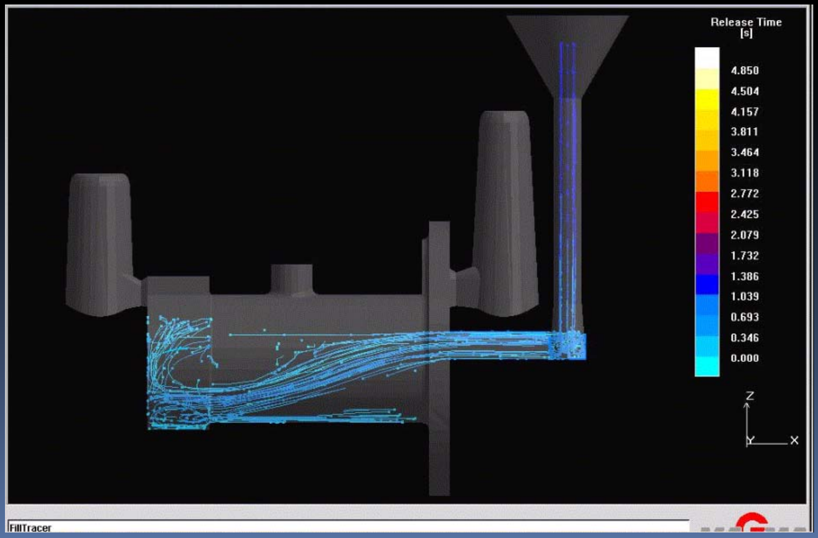
✓Simulation by FactSage software (developed at École Polytechnique de Montréal); this software assumes equilibrium is reached.

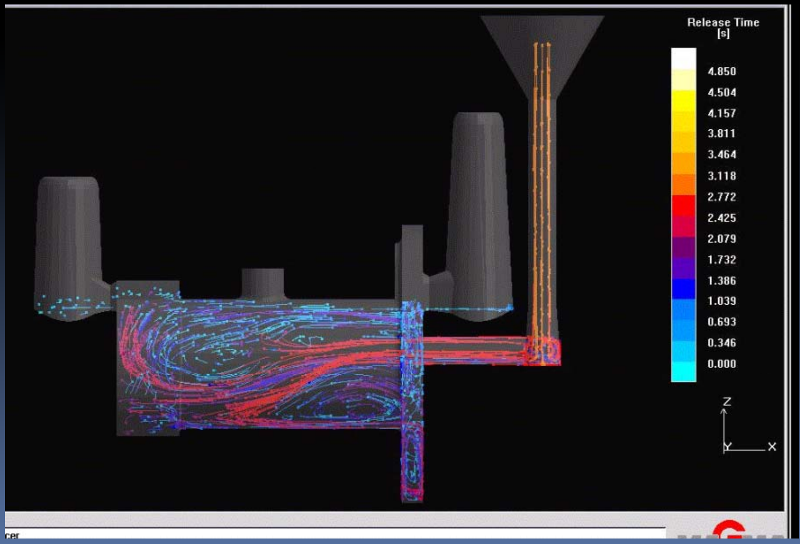
FORMATION, EXPLANATION & SIMULATION:

✓Thermodynamic simulations were carried out to determine under which conditions dross would form

✓Parameters:

- %S : 0,010 & 0,020;
- %Si: 2,0 & 2,5;
- %Mg: 0,04 – 0,06%;
- Temp.: 1300 to 1500C;
- Oxygen: 10 to 1000 ppm to simulate turbulence!





FORMATION, EXPLANATION & SIMULATION:

Magnesium compounds formation

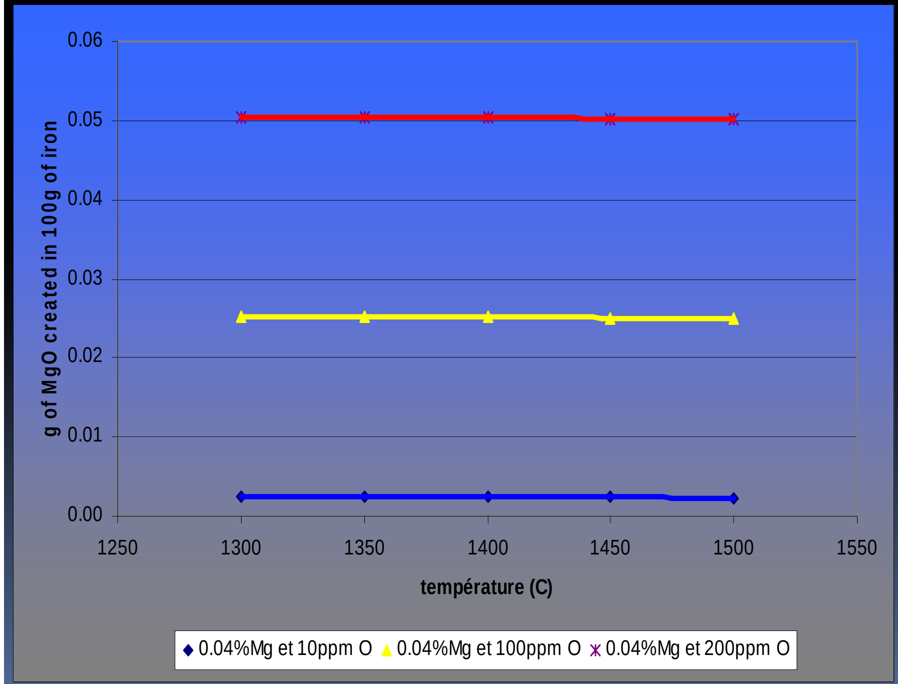
- **%S: 0,010**
- **%Si: 2,0**
- **%Mg: 0.04 & 0.05**
- **%O: 10, 100 & 200 ppm**
- **Temperature: 1300-1500 C**

FORMATION, EXPLANATION & SIMULATION:

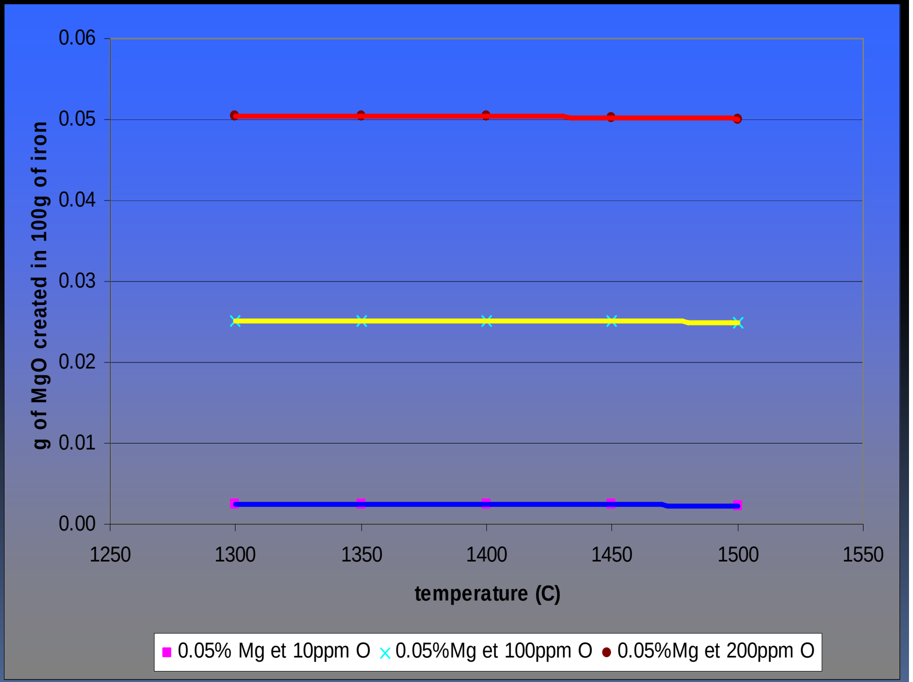
Magnesium compounds formation

Magnesium Oxide with % Mg = 0.04 – 0.05

0.04 %



0.05 %

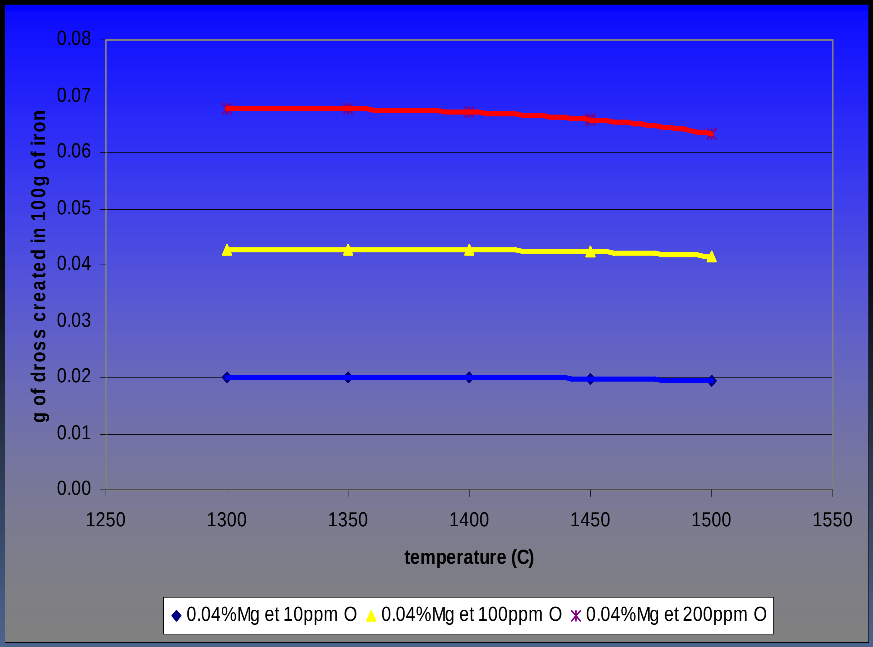


FORMATION, EXPLANATION & SIMULATION:

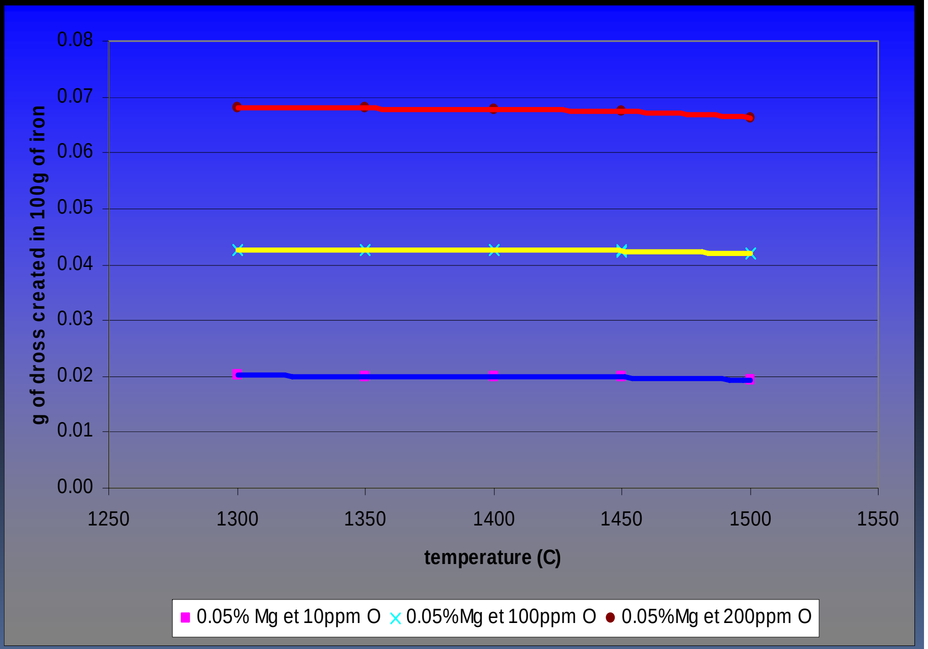
Magnesium compounds formation

Magnesium Silicite (Mg_xSi_y) with % Mg = 0.04 – 0.05, 2,0% Si

0.04 %



0.05 %

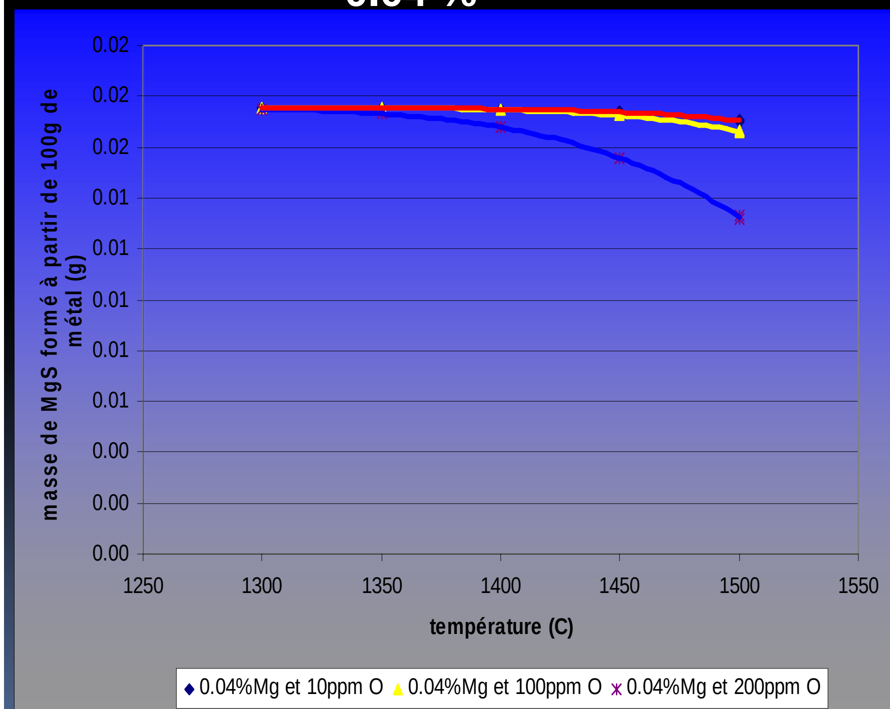


FORMATION, EXPLANATION & SIMULATION:

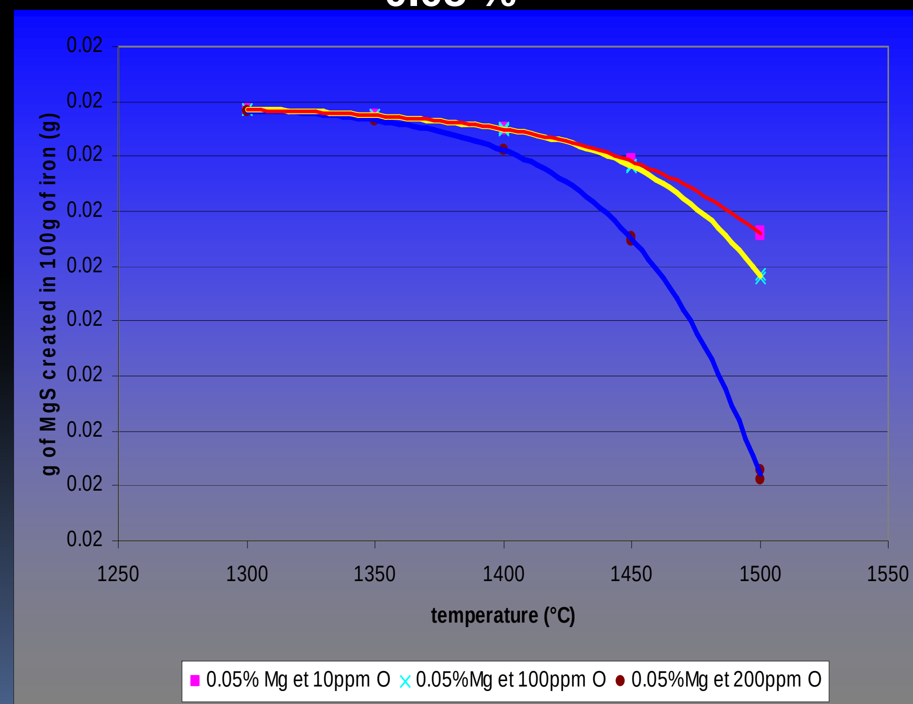
Magnesium compounds: 1° step of dross simulation

Magnesium Sulphide with % Mg = 0.04 – 0.05, 0,010% S

0.04 %



0.05 %

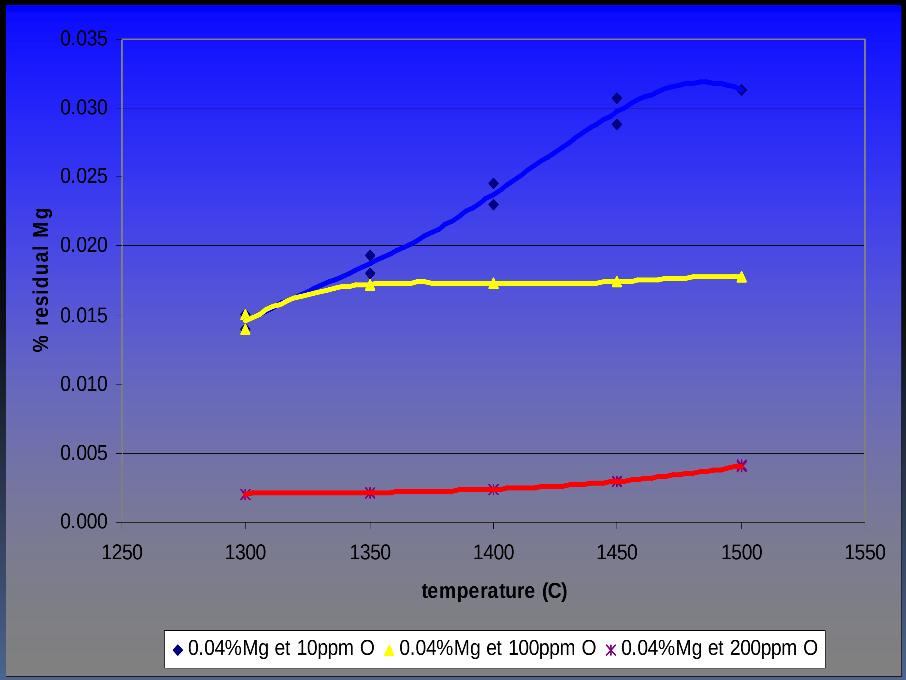


FORMATION, EXPLANATION & SIMULATION:

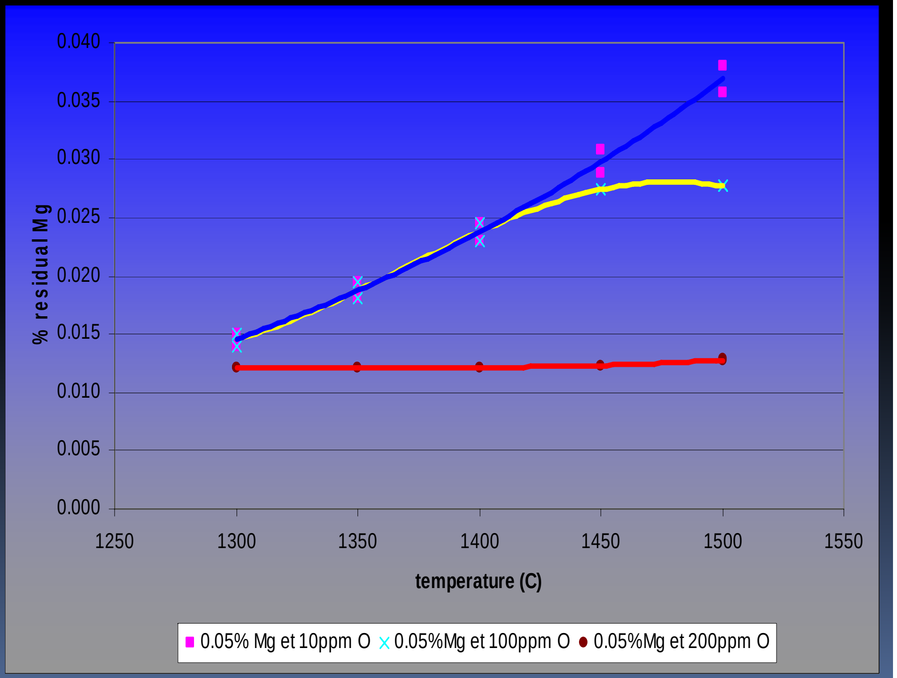
Magnesium compounds: 1° step of dross simulation

"Residual = Free" Magnesium with % Mg = 0.04 – 0.05

0.04 % of Mg



0.05 % of Mg



FORMATION, EXPLANATION & SIMULATION:

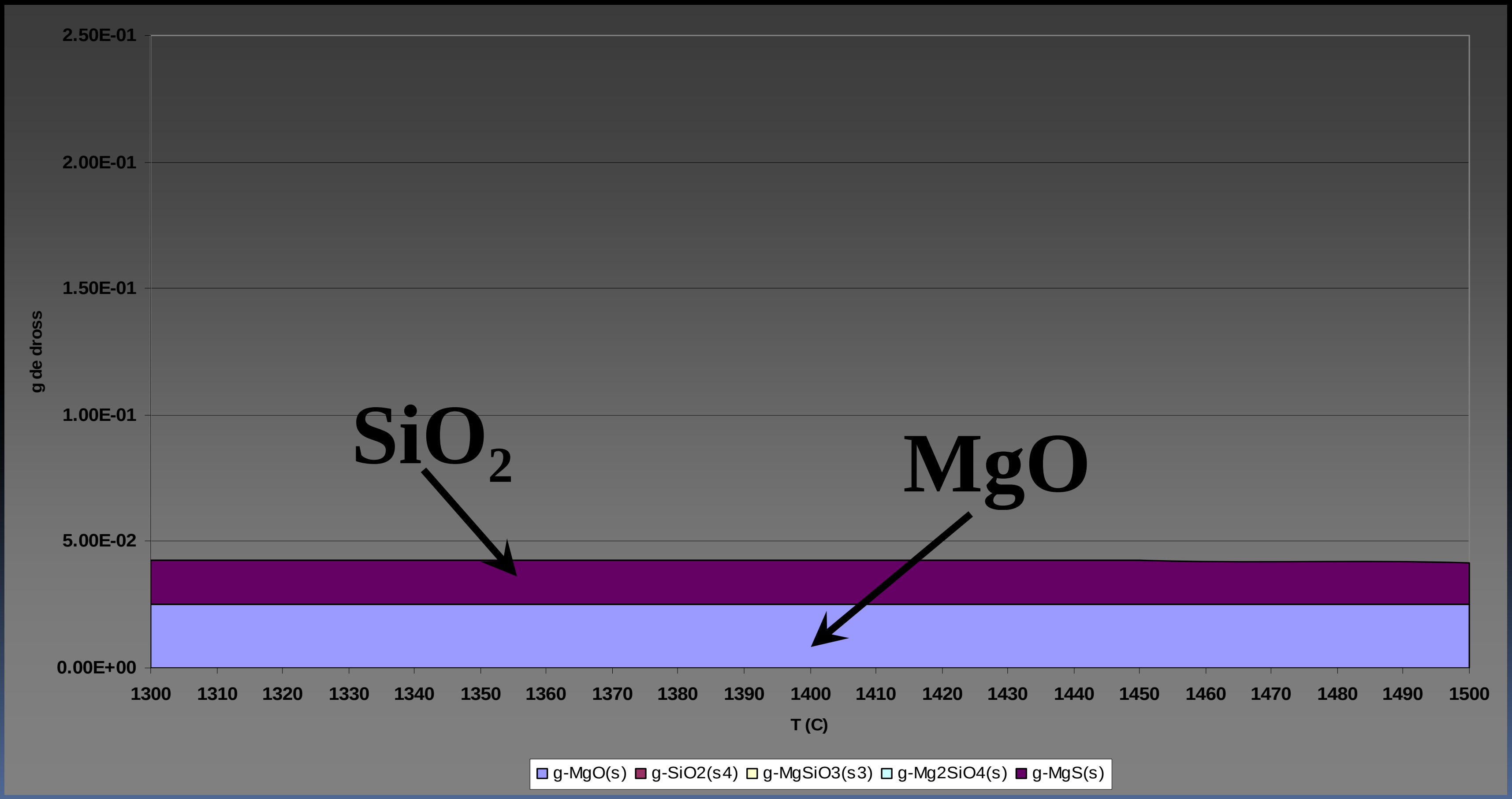
Effect of Temperature

- **% S: 0,001**
- **% Si: 2,0**
- **% Mg: 0,04**
- **Oxygen: 100, 300, 500, 700 &1000 ppm**
- **Temperature: 1300-1500 C**

FORMATION, EXPLANATION & SIMULATION:

Effect of Temperature

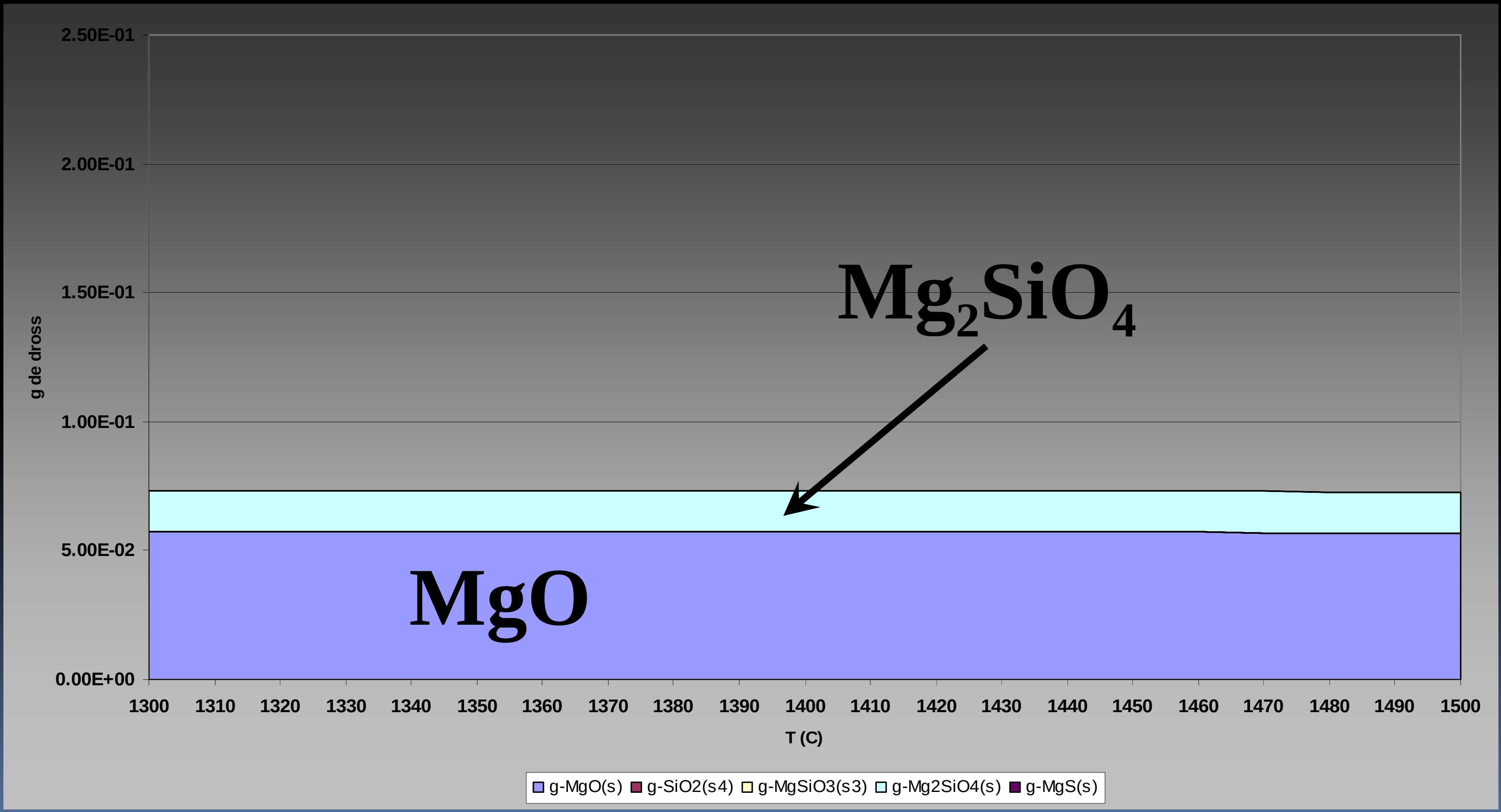
Dross formation vs Temperature for 0.04% Mg, 2% Si & 100ppm O_2



FORMATION, EXPLANATION & SIMULATION:

Effect of Temperature

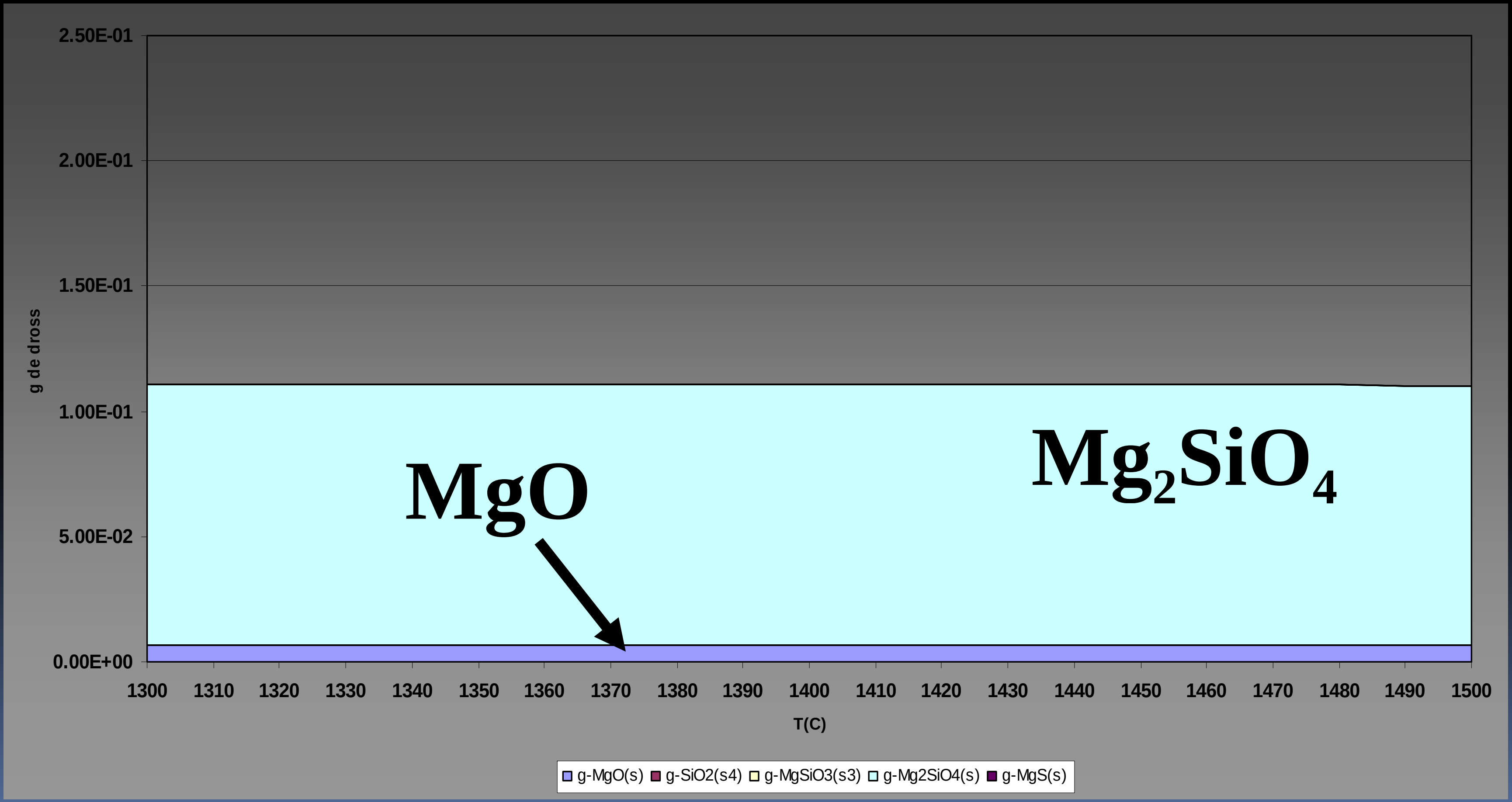
Dross formation vs Temperature for 0.04% Mg, 2% Si & 300ppm O_2



FORMATION, EXPLANATION & SIMULATION:

Effect of Temperature:

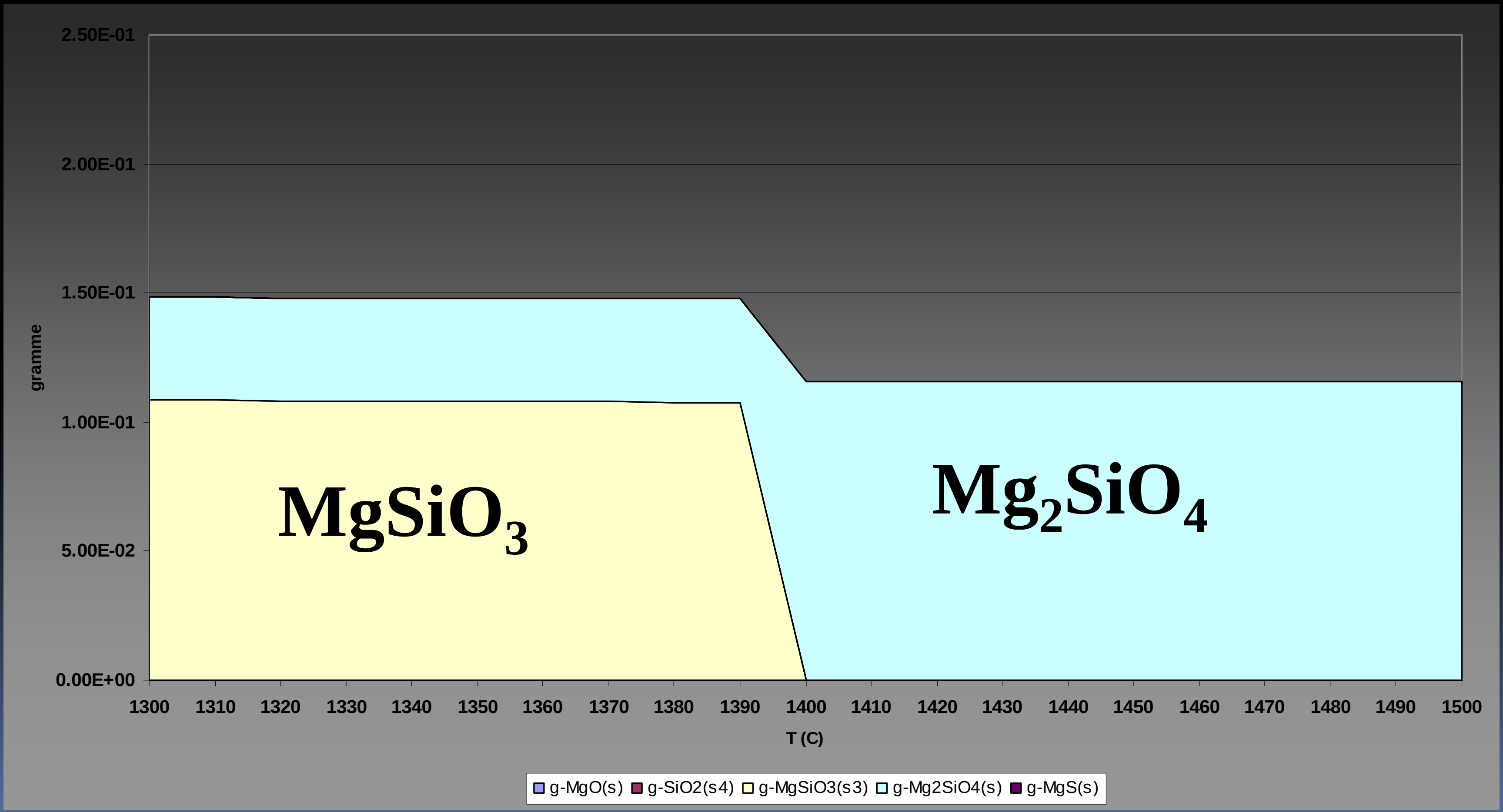
Dross formation vs Temperature for 0.04% Mg, 2% Si & 500ppm O_2



FORMATION, EXPLANATION & SIMULATION:

Effect of Temperature

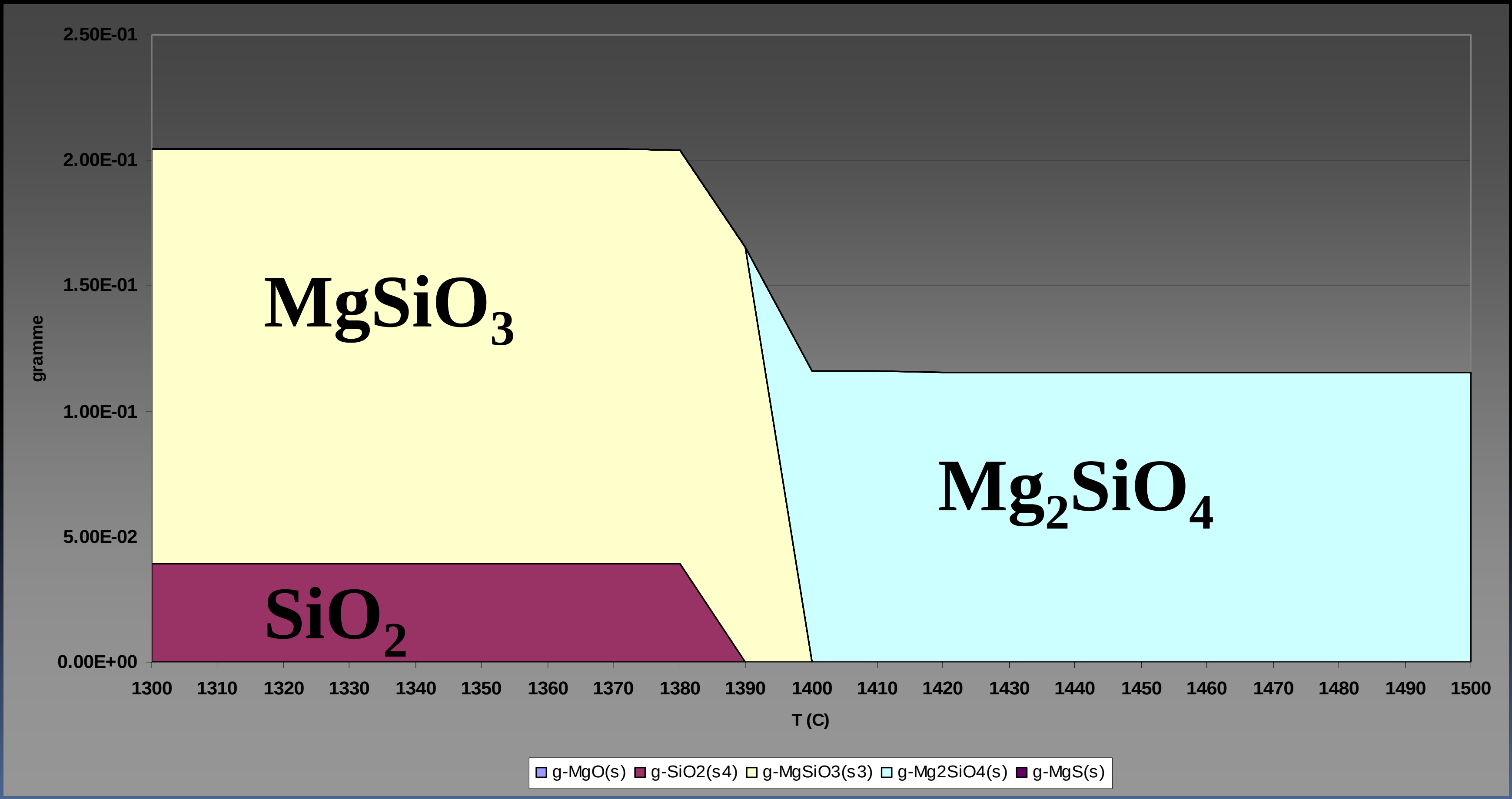
Dross formation vs Temperature for 0.04% Mg, 2% Si & 700ppm O_2



FORMATION, EXPLANATION & SIMULATION:

Effect of Temperature

Dross formation vs Temperature for 0.04% Mg, 2% Si & 1000ppm O_2

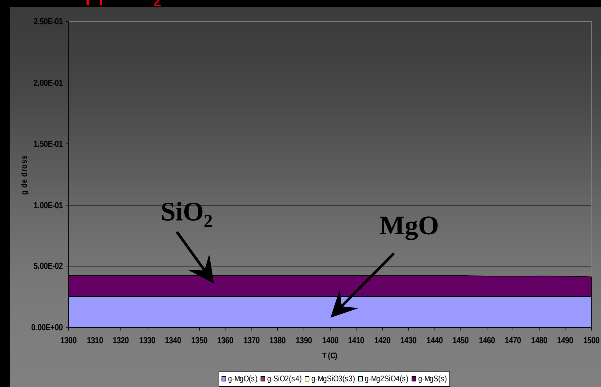


FORMATION, EXPLANATION & SIMULATION:

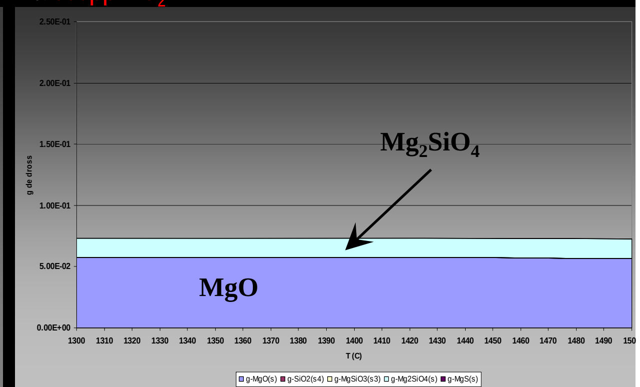
Effect of Temperature: Summary

Summary

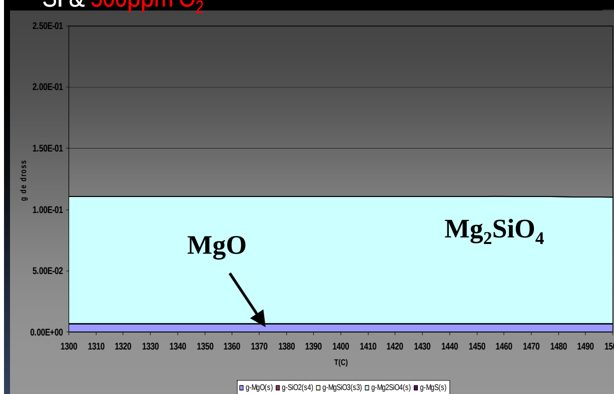
Dross formation vs Temperature for 0.04% Mg, 2% Si & 100ppm O_2



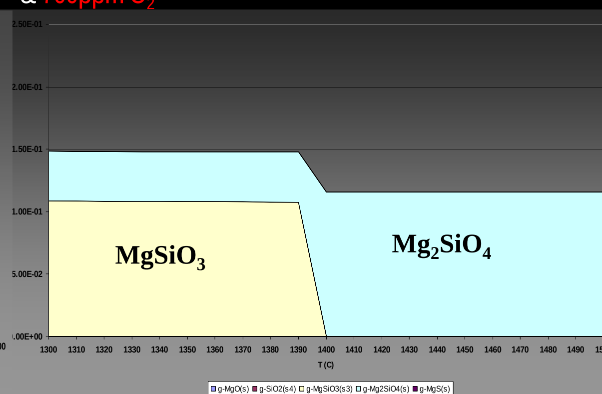
Dross formation vs Temperature for 0.04% Mg, 2% Si & 300ppm O_2



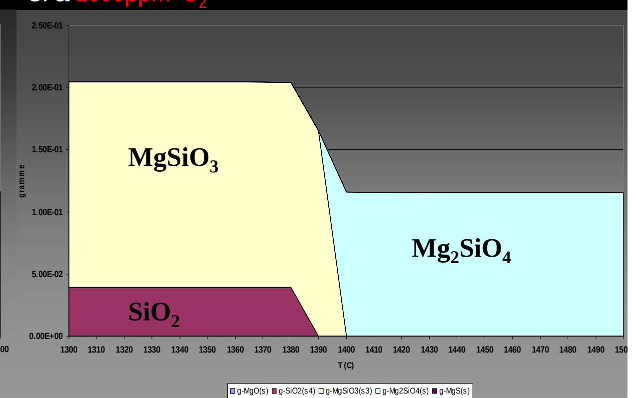
Dross formation vs Temperature for 0.04% Mg, 2% Si & 500ppm O_2



Dross formation vs Temperature for 0.04% Mg, 2% Si & 700ppm O_2



Dross formation vs Temperature for 0.04% Mg, 2% Si & 1000ppm O_2



At high Temperature, dross level is similar

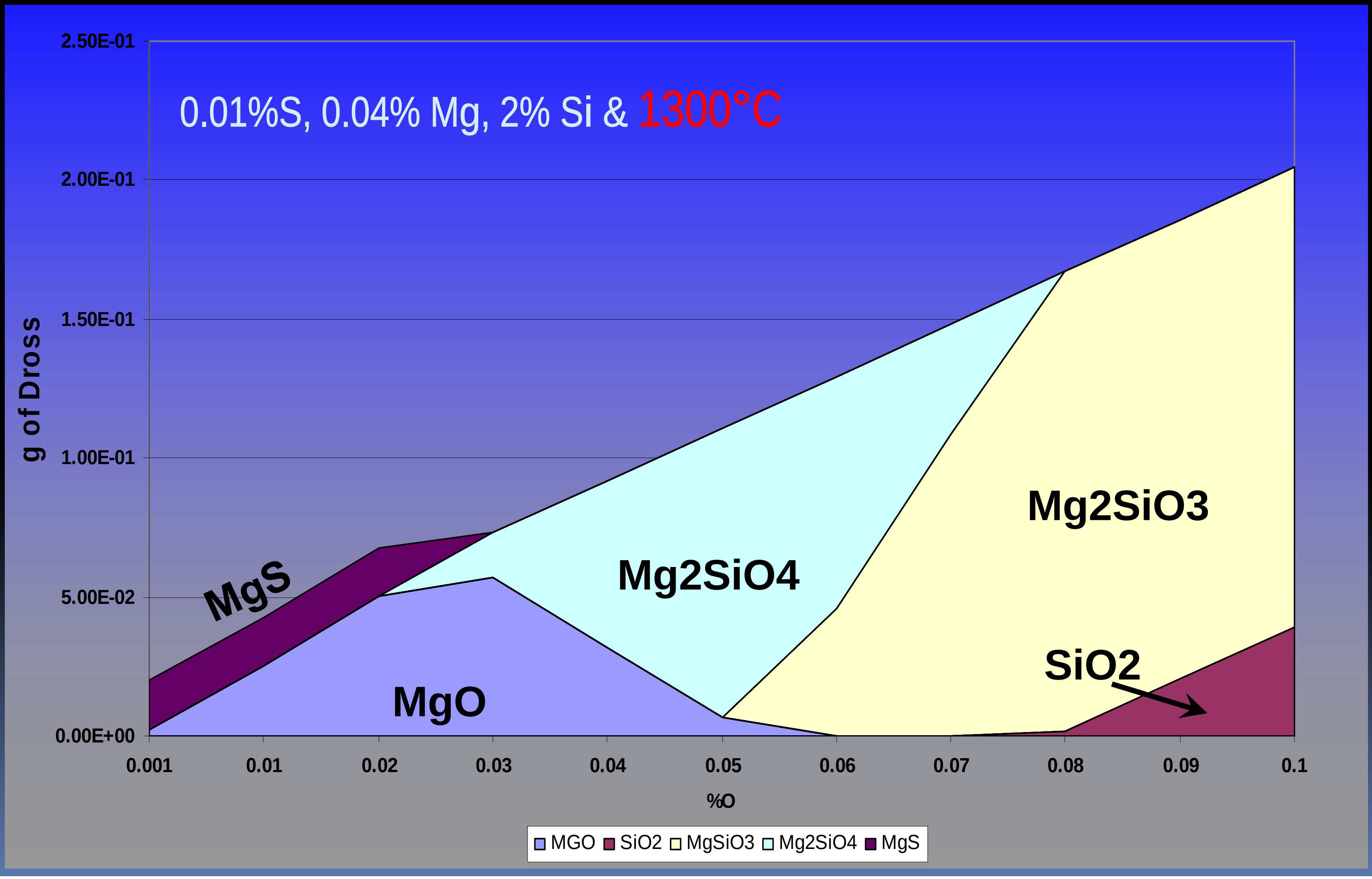
FORMATION, EXPLANATION & SIMULATION:

Effect of Oxygen Content (turbulence)

➢% Sulphur:	0.010	0.020
➢%Magnesium:	0.040	0.060
➢% Silicon:	2.00	2.50
➢°C Temperature:	1300 and 1500	
➢ppm Oxygen:	from 10 to 1000	

FORMATION, EXPLANATION & SIMULATION:

Effect of Oxygen Content (turbulence)



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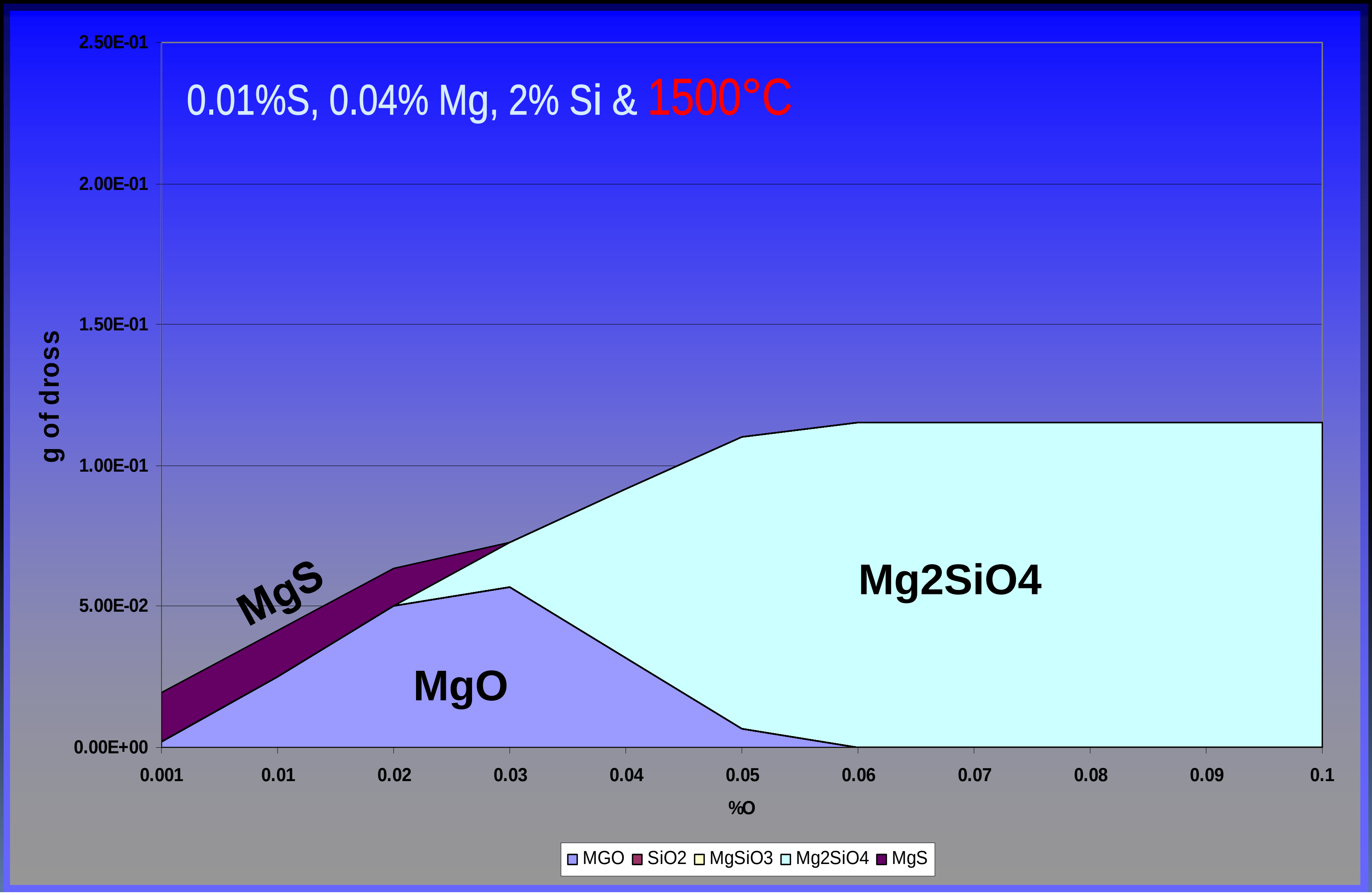
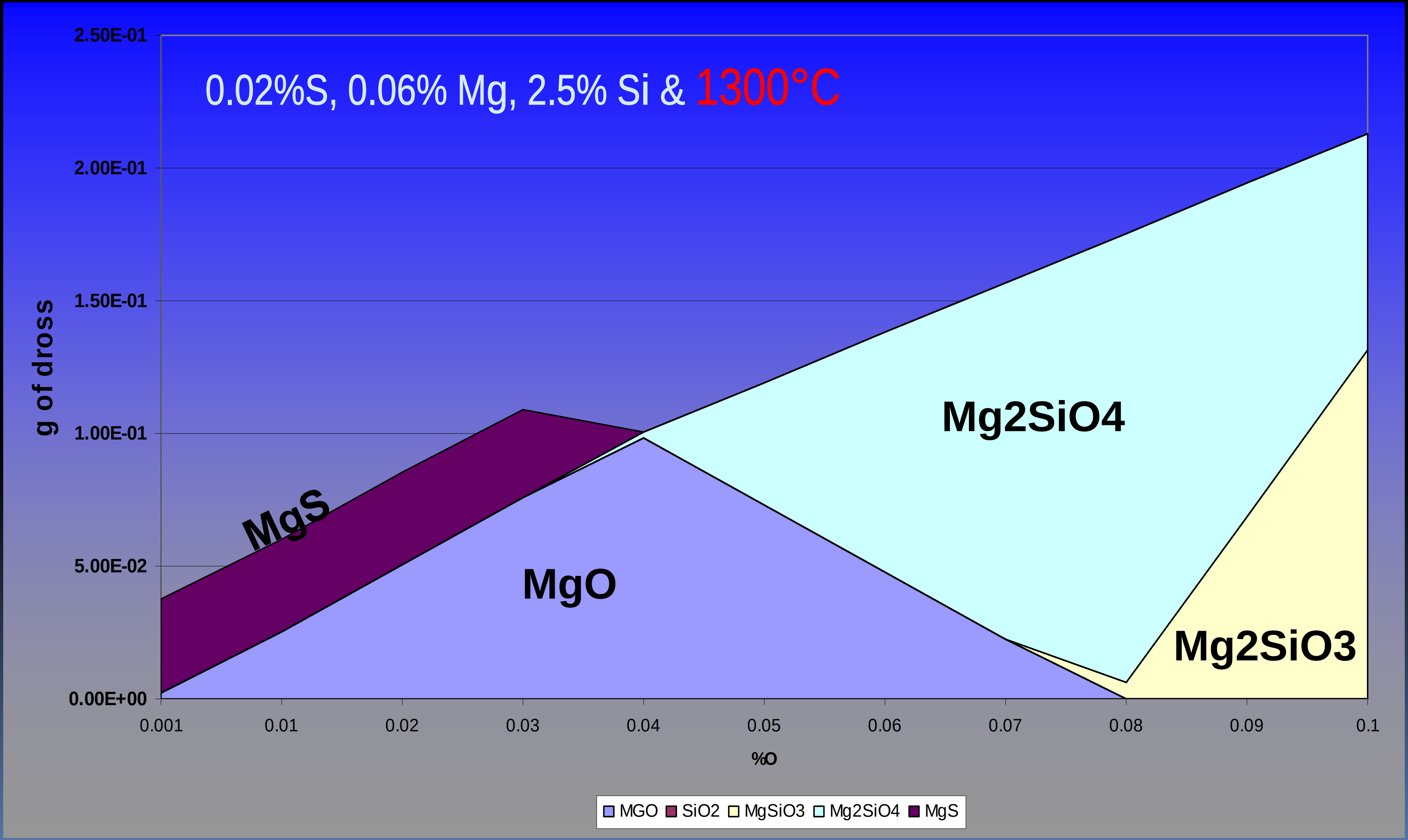
Effect of Oxygen Content (turbulence)



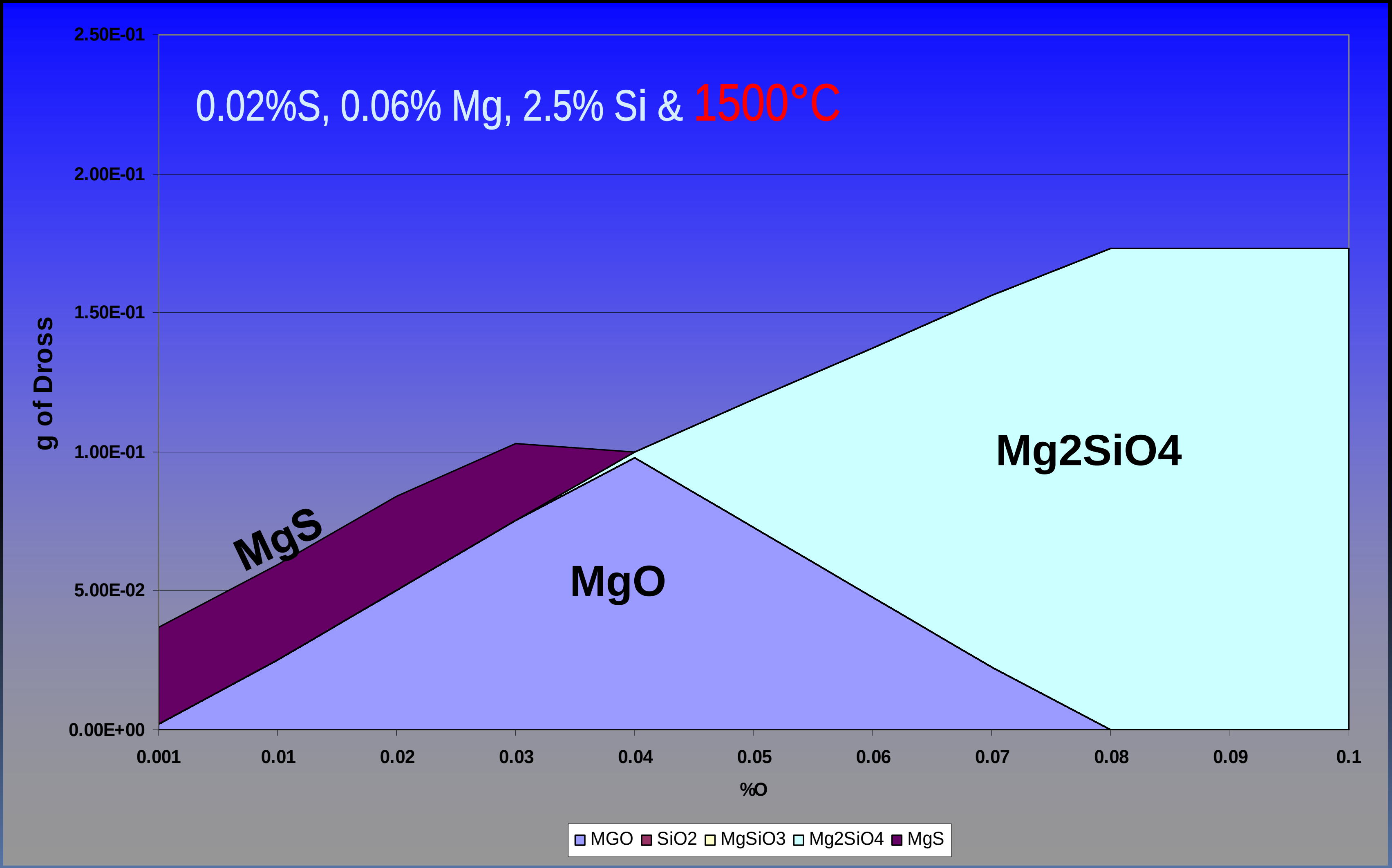
FORMATION, EXPLANATION & SIMULATION:

Effect of Oxygen Content (turbulence)



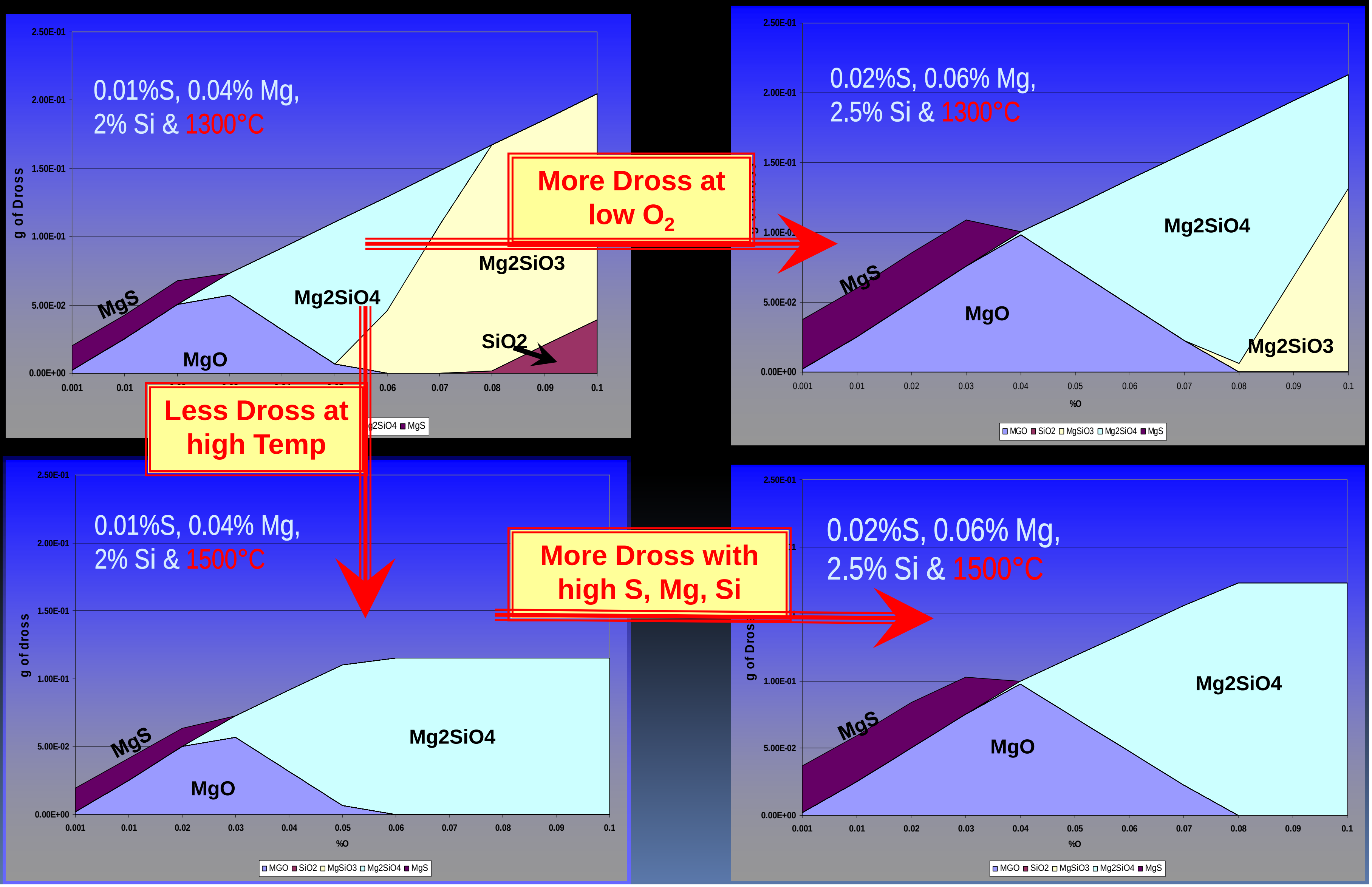
FORMATION, EXPLANATION & SIMULATION:

Effect of Oxygen Content (turbulence)



FORMATION, EXPLANATION & SIMULATION:

Effect of Oxygen Content: Summary



CONCLUSIONS:

- ✓Formation of dross is mainly controlled by oxygen content; the level of oxygen required suggests that an external source of oxygen is needed: turbulence!
- ✓Dross is mainly a “mixture” of magnesium silicates;
- ✓Dross formation is favored by low pouring temperature, turbulence, high %Mg and high %Si;
- ✓If all other parameters are kept under control, the effect of pouring temperature is minimized;
- ✓Sulphur, at low level, does not interact with dross formation.
- ✓Composition of dross changes with temperature.

Thanks!

Gracias!

Merci!

Martin Gagné, Marie-Pierre Paquin,
Pierre-Marie Cabanne

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