CEMARE

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Transverse shrinkage of poplar tension wood at cell wall level

Changhua FANG[1,2], Bruno CLAIR[1], Joseph GRIL[1], Shengquan LIU[2]

1) Laboratoire de Mécanique et Génie Civil, University Montpellier 2, France
2) Forest Products Department, Anhui Agricultural University, Hefei, China

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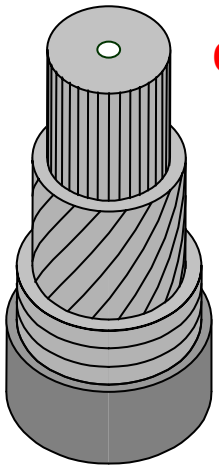
- # INTRODUCTION

Tension wood and gelatinous layer

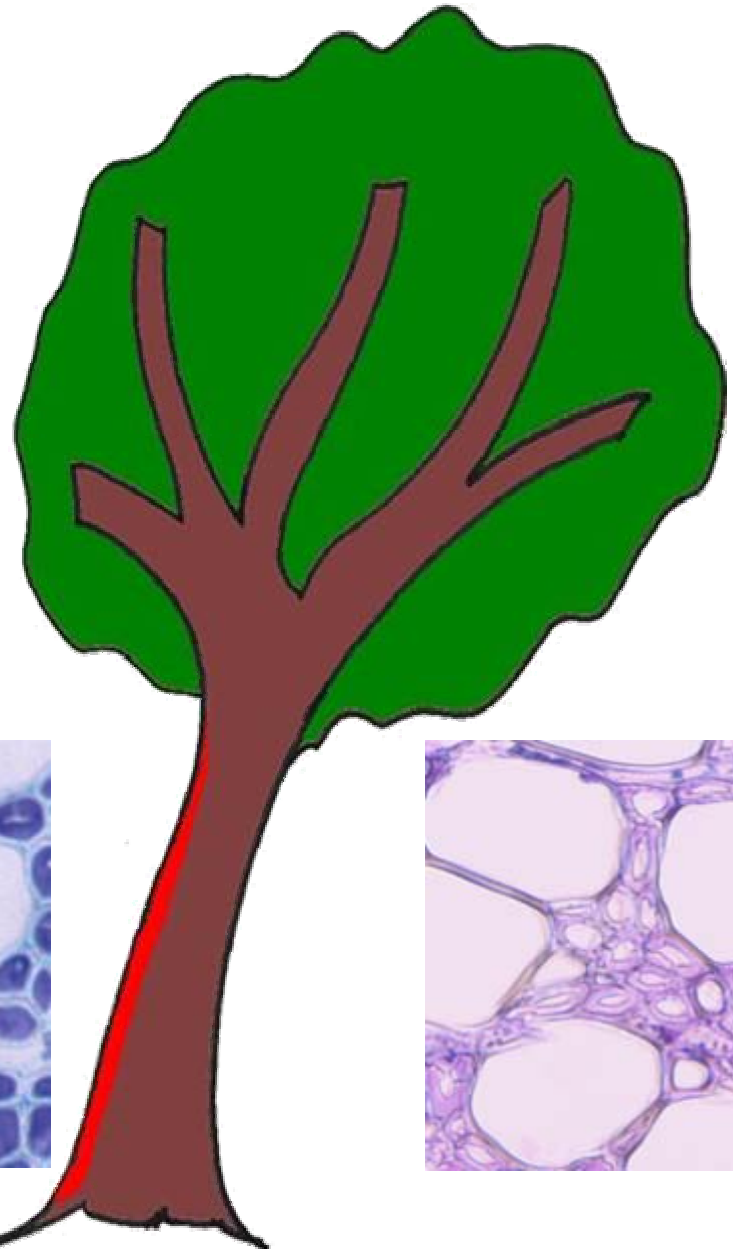


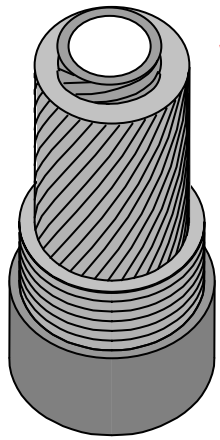
G

S 2

S 1

CL + P



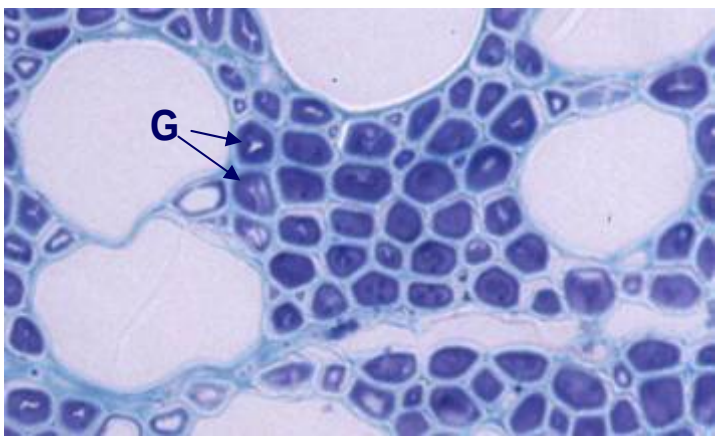


S 3

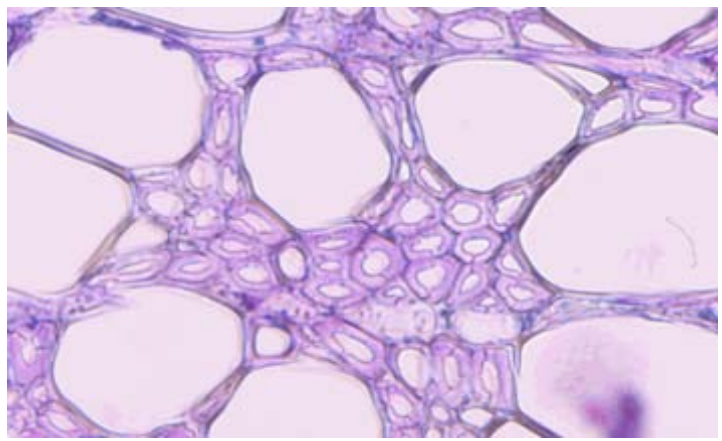
S 2

S 1

CL + P



Tension wood

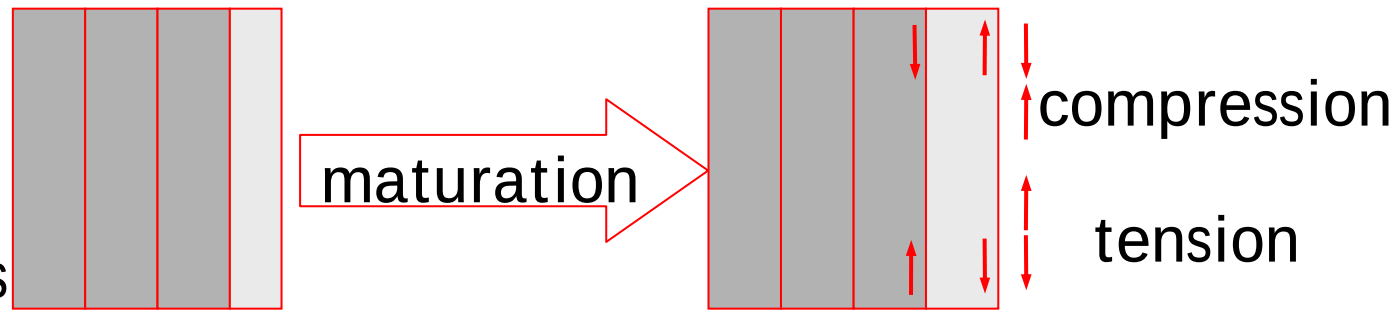


Normal wood

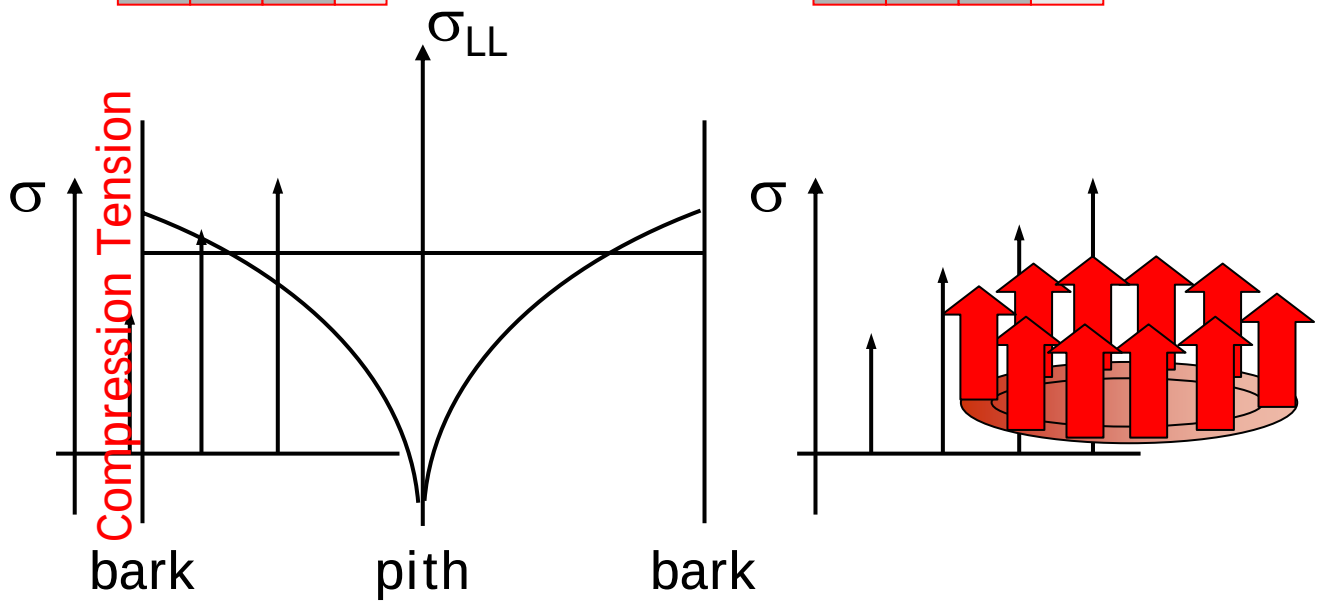
Growth stresses

Single cell

The same cell sticking to older cells



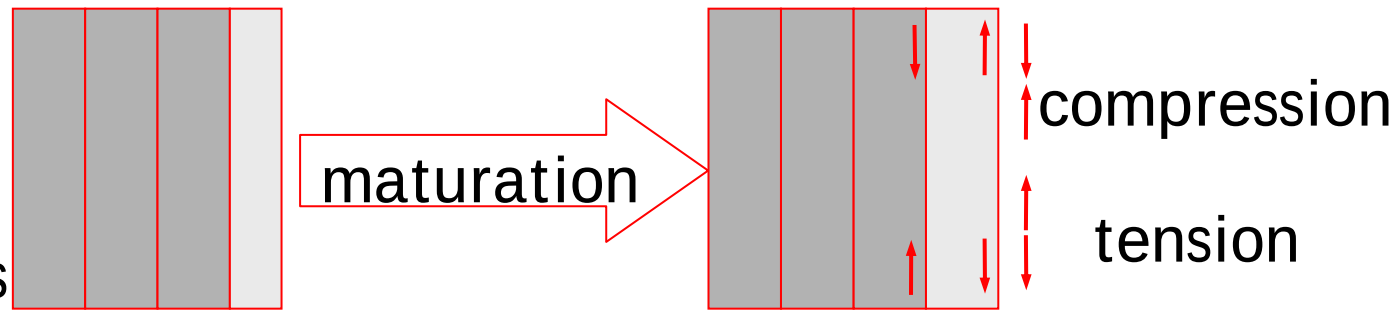
Stress profiles

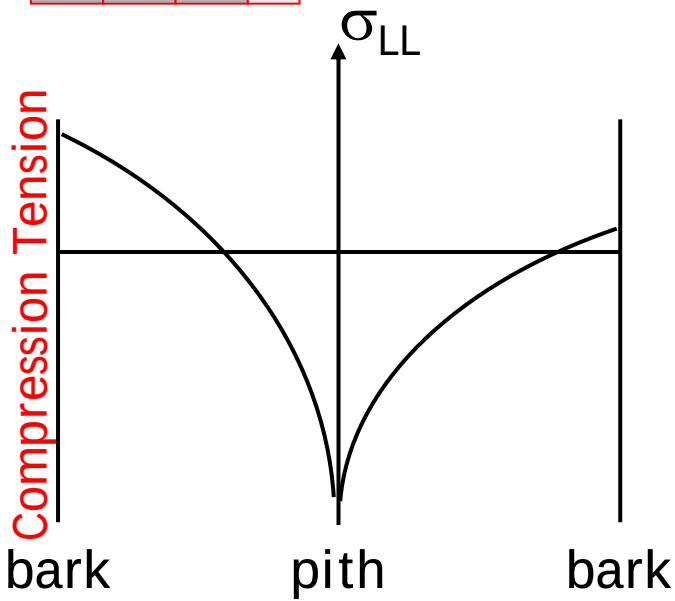


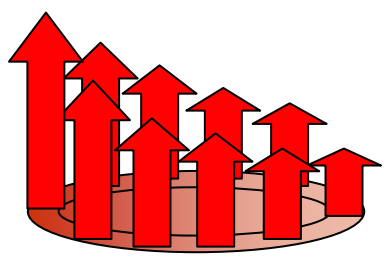
Growth stresses

Single cell

The same cell sticking to older cells







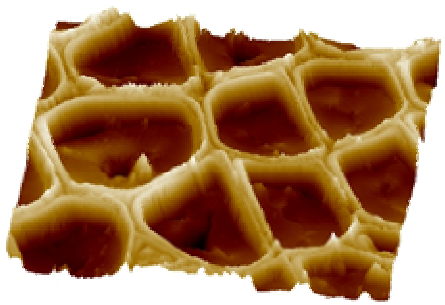
Tension wood shrinkage

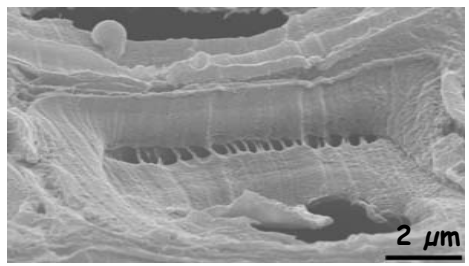
- Longitudinal shrinkage

Higher in tension wood than in normal wood

1) High longitudinal shrinkage is produced by S1 layer, G-layer being unable to prevent it.

2) Higher longitudinal shrinkage in G-layer than in other layers. (After B.Clair et al. 2001)





- Transverse shrinkage

Contradictory results were found by different researchers.

Washusen(2001) and Clair(2001):Higher in tension wood.

Arganbright(1970) and Barefoot(1963):Lower in tension wood.

Objective

In this paper we concentrate on transverse shrinkage:

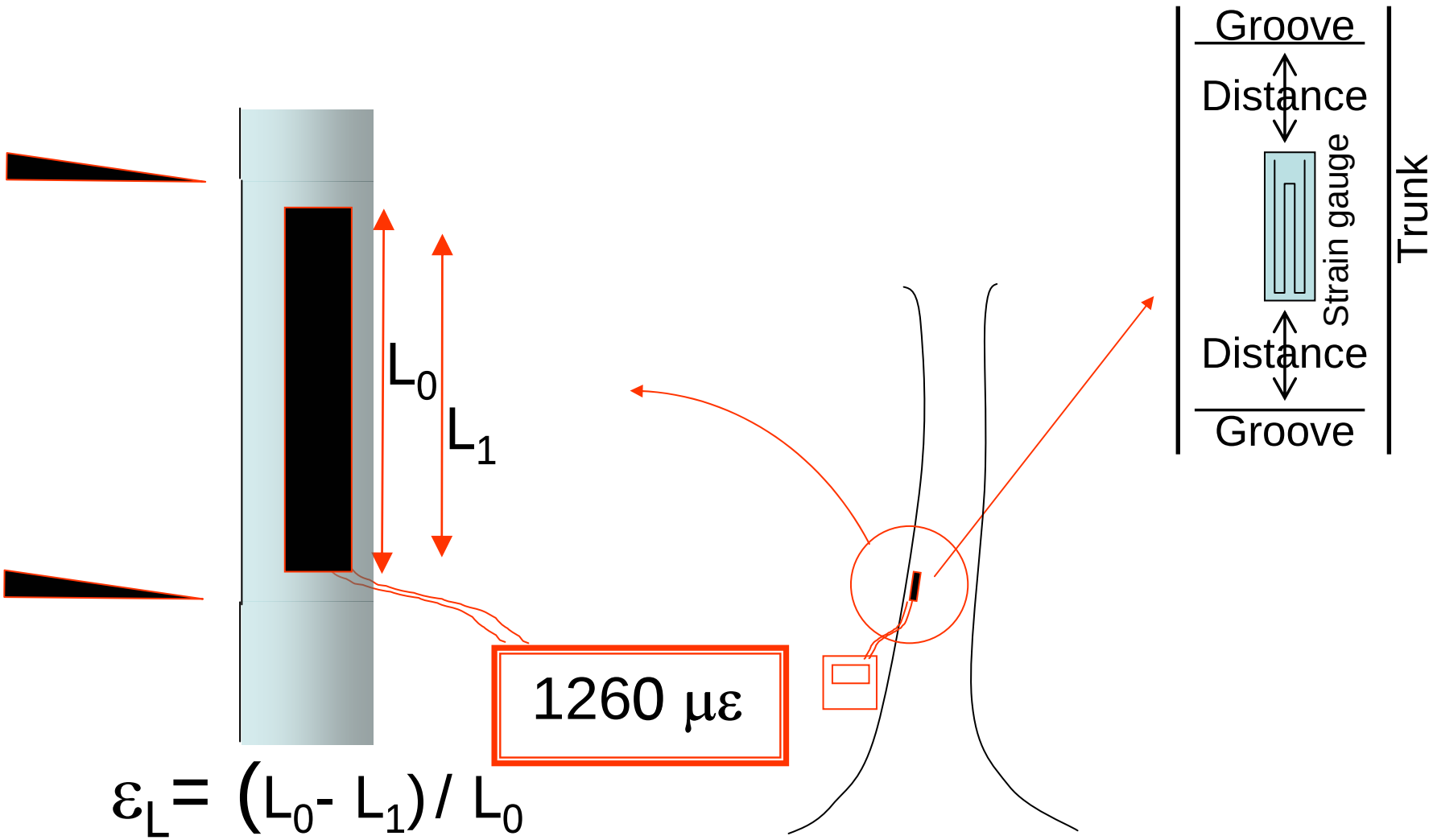
- At the microscopic level (0.5 - 10 µm):
  - Are there any shrinkage differences
    - between G-layer and the other layers?
    - among G-layers in different levels of tension wood?
- At the mesoscopic level (5 - 10 mm)
  - Are there any shrinkage differences
    - between normal wood and tension wood?
    - among different levels of tension wood?
- Contribution of G-layer and other layers to the mesoscopic shrinkage of tension wood.

- **Material and methods**

Species

- Poplar tension wood (*Populus* I 45-51).
- Known to have a characteristic tension wood with G-fibres and to produce high longitudinal tensile stress.
- Tree was chosen according to its tilted shape.

Growth Strain (GS)



$$\varepsilon_L = (L_0 - L_1) / L_0$$

$$\mu\varepsilon = \mu m/m = \varepsilon \times 10^6$$

Growth Strain (GS)

25 GS values from 100 to 2275με were obtained.

None or very few G-fibre when GS $\leqslant$ 610με

Shrinkage measurement at the cell wall level:
2275 με, 1935 με, 1450 με, 1158 με, 816 με, 610 με

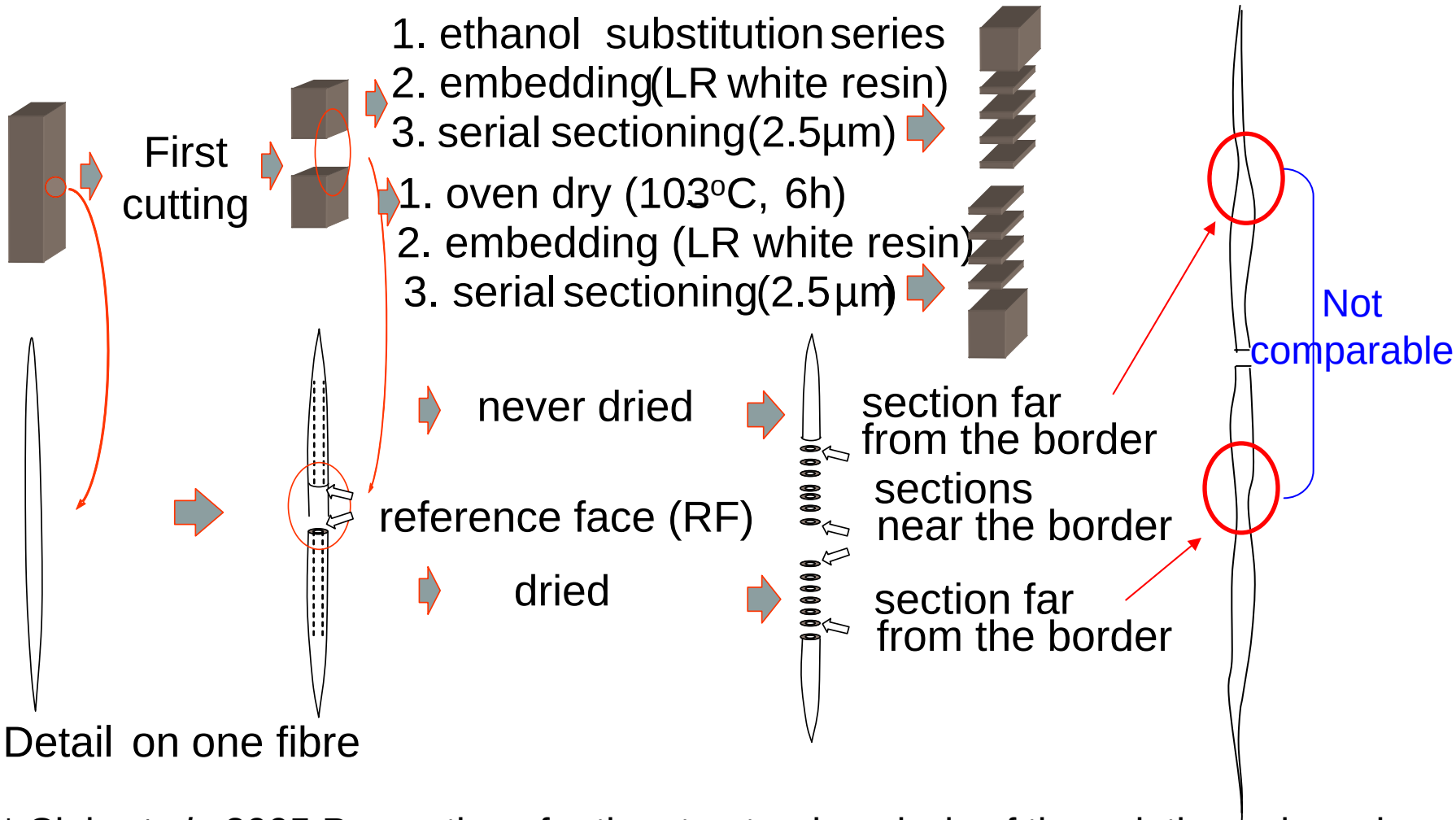
Shrinkage measurement at the mesoscopic scale:
2275 με, 1935 με, 1450 με, 1158 με, 816 με, 610 με, 405 με, 168 με

Tension Wood

Normal wood

Shrinkage measurement at microscopic level

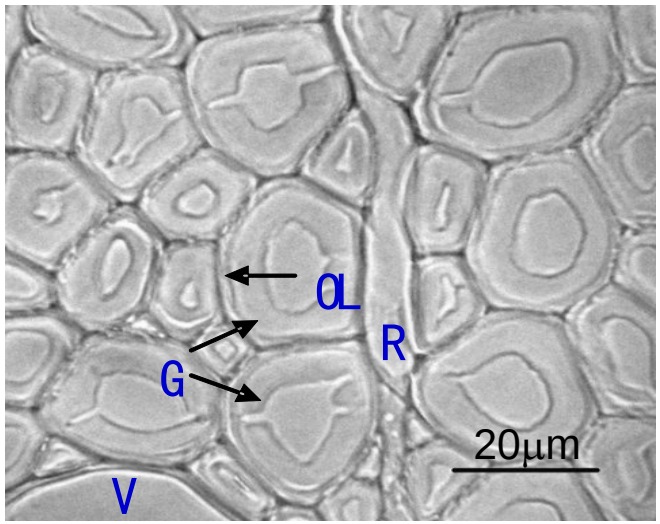
- Samples preparation and Sectioning

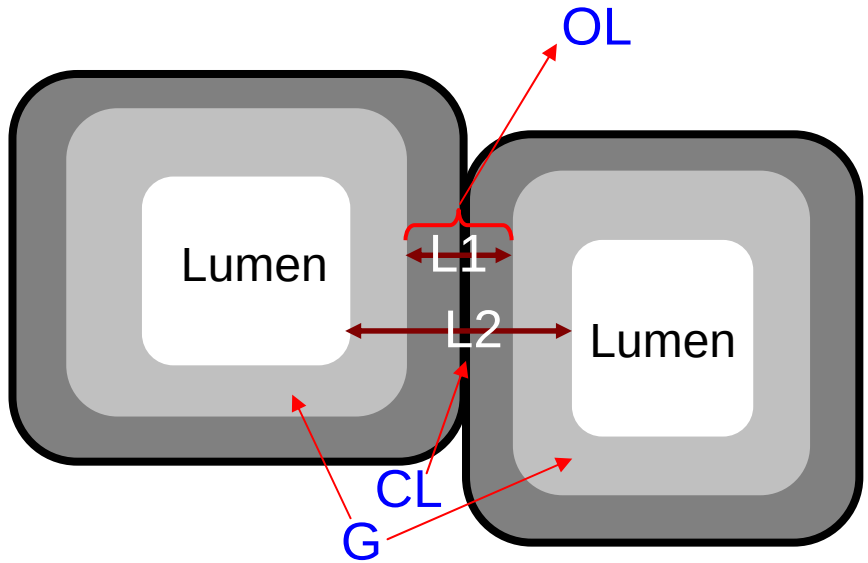


* Clair *et al*., 2005 Precautions for the structural analysis of the gelatinous layer in tension wood. *IAWA Journal, 26*(2), 189-195.

Shrinkage measurements at microscopic level

- Measurements





G: G-layer; V: vessel; R: ray;

OL: Other layers including S_2(?), S_1, P, and compound lamella (CL).

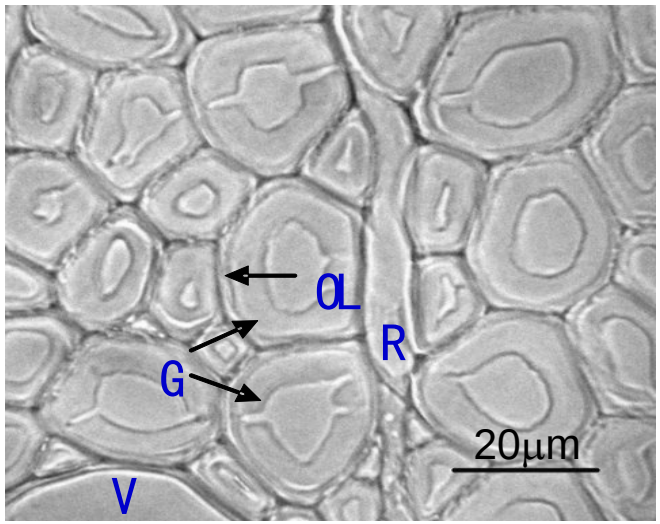
OL thickness = L1/2

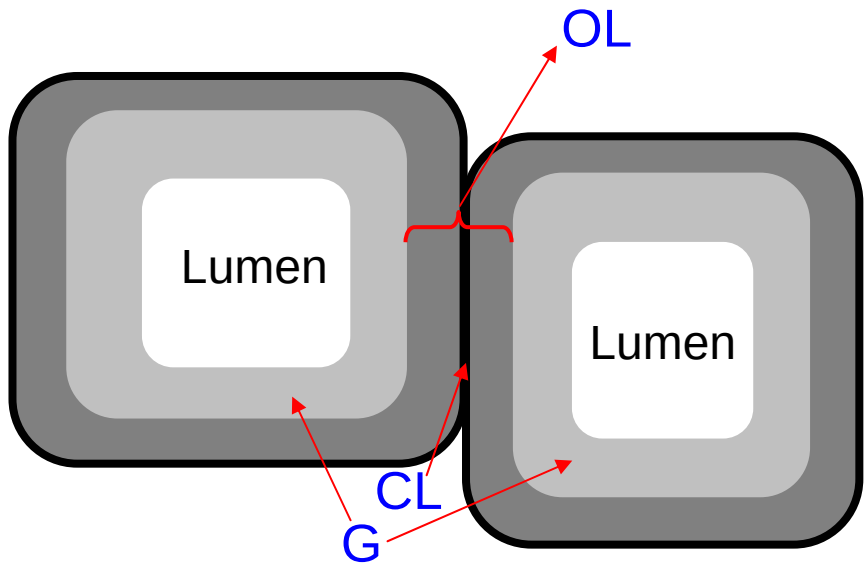
G-layer thickness = (L2-L1)/2

Total cell wall thickness = L2/2

Shrinkage measurements at microscopic level

- Measurements





G: G-layer; V: vessel; R: ray;

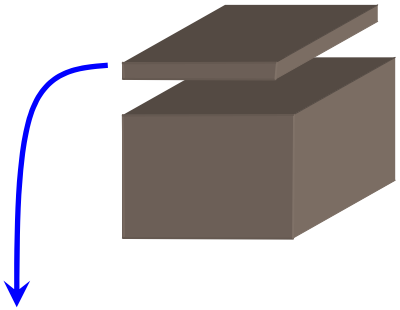
OL: Other layers including S_1, S_2 and compound lamella (CL).

Area { Lumen / Total Cell Perimeter { Lumen / Total Cell

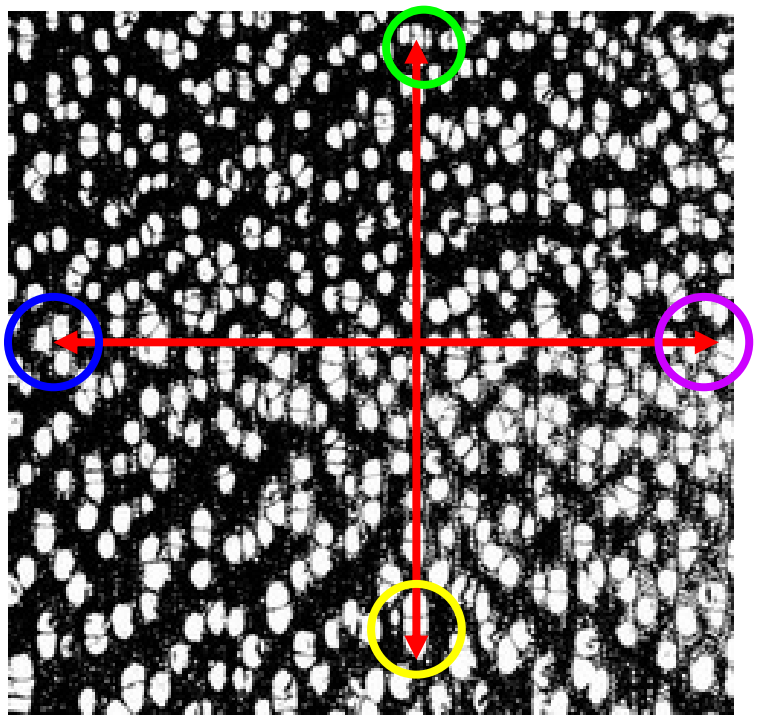
Diameter = $2 \times (\text{Area}/\pi)^{1/2}$

Perimeter → Tangential shrinkage

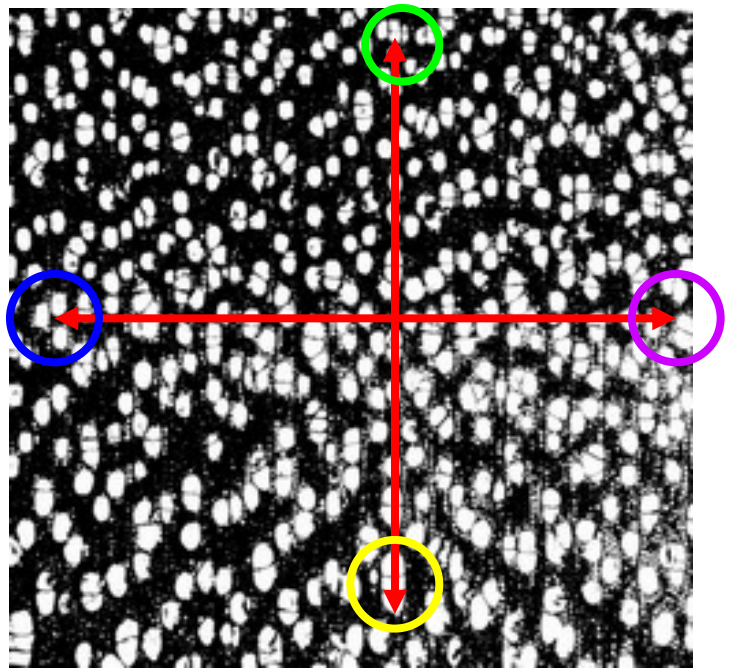
Shrinkage measurement at mesoscopic level



Wet sample($7 \times 7 mm^2$)
with normal sectioning



Before dried

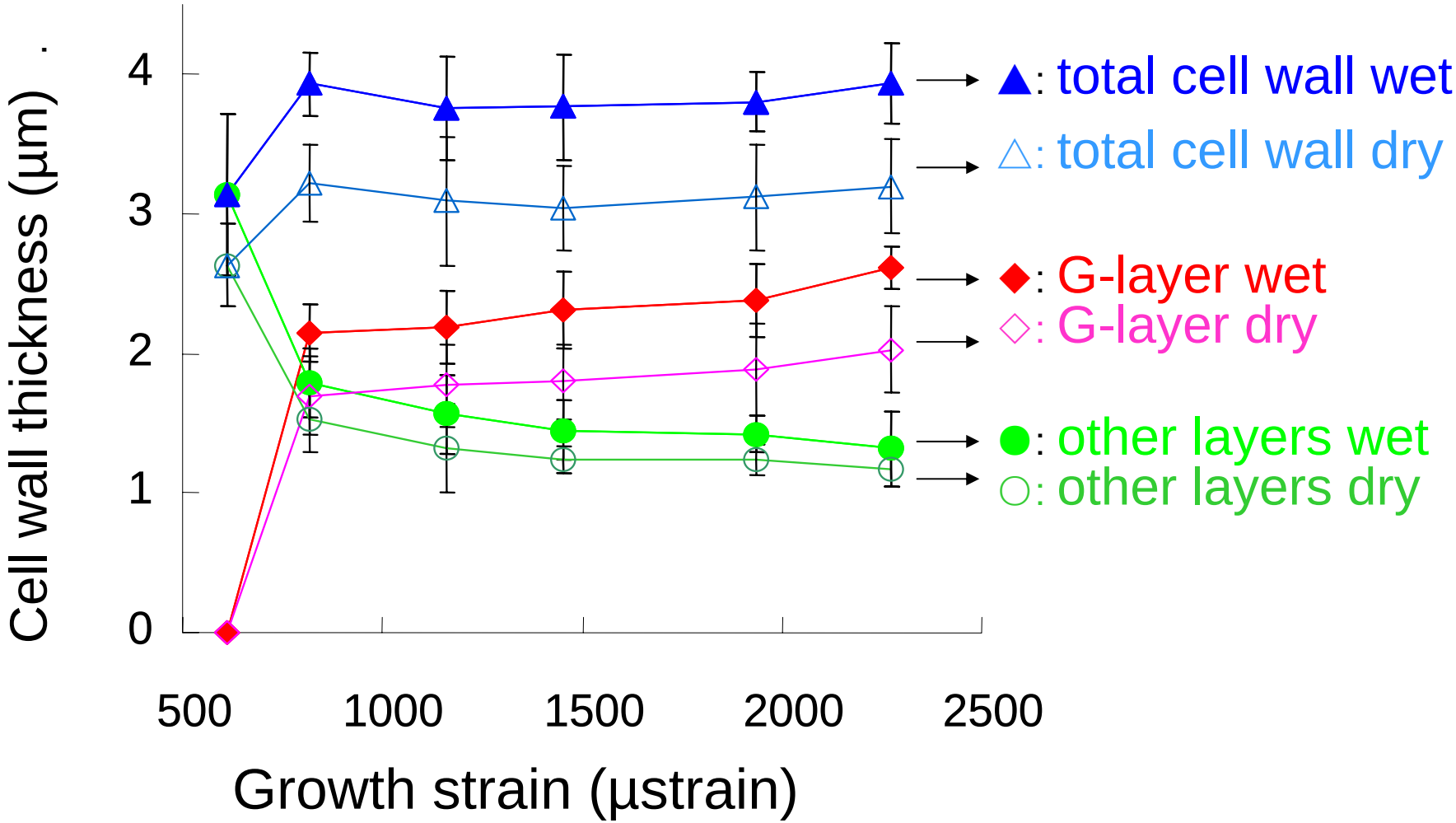


After dried

- **Results and discussion**

Shrinkage at microscopic level

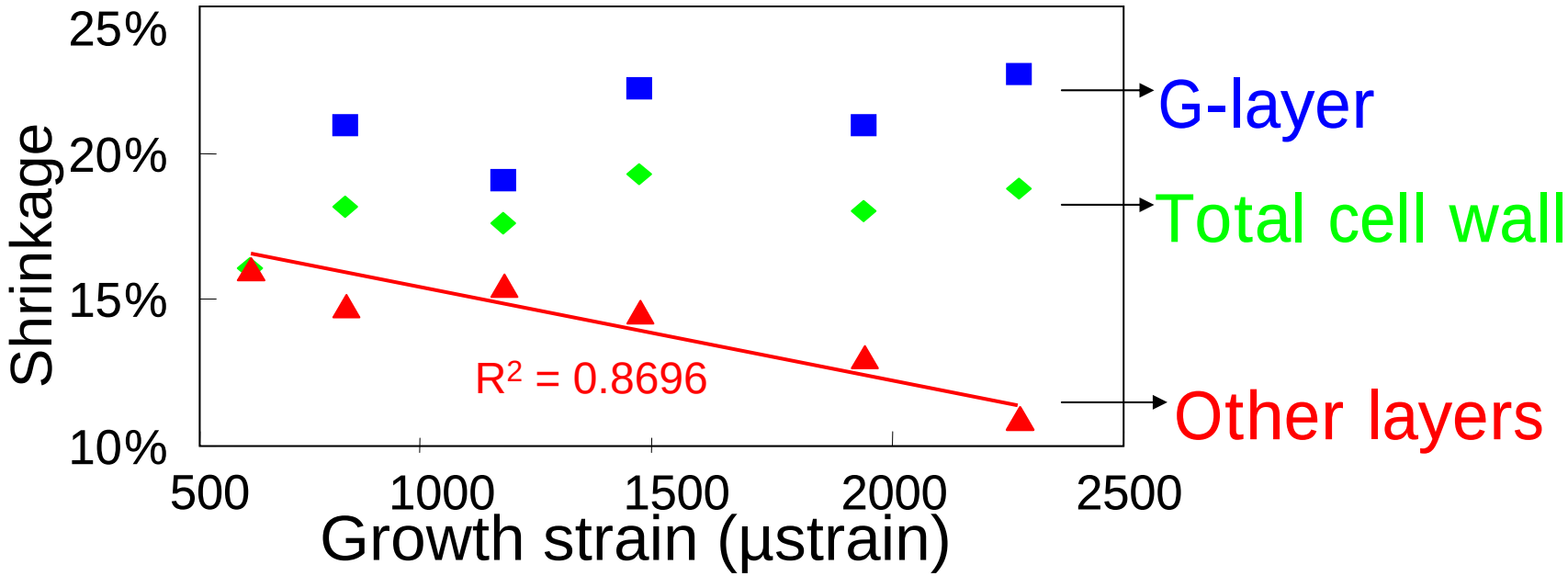
- Cell wall thickness -GS



Error bars show the standard deviations.

Shrinkage at microscopic level

- Cell wall Shrinkage -GS

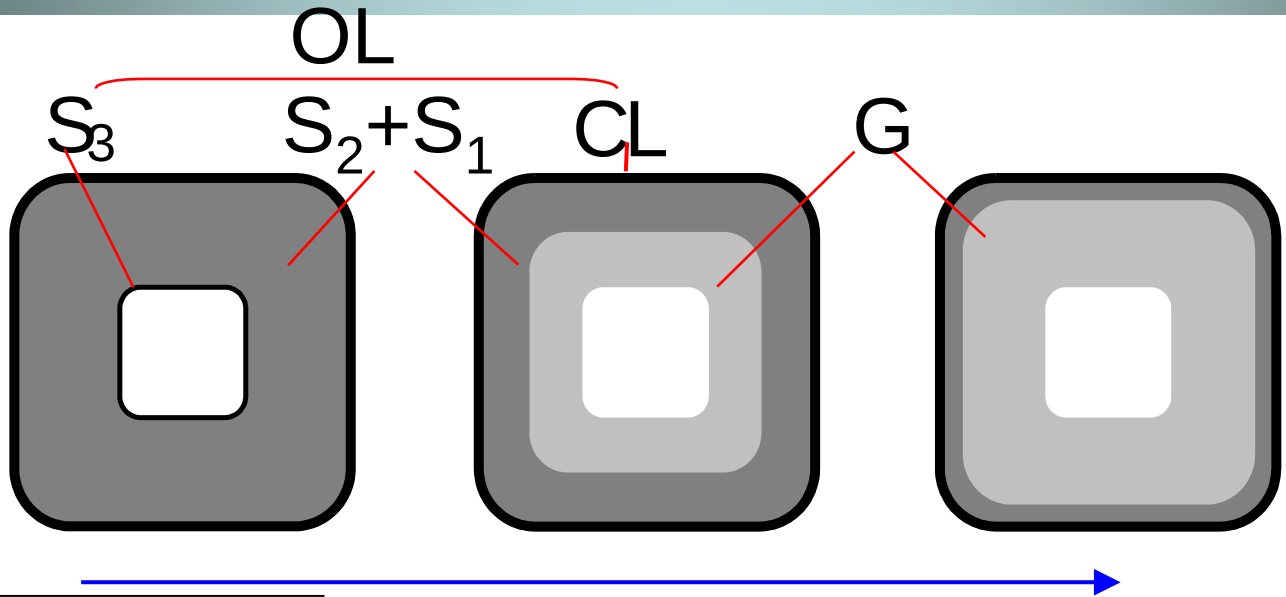


•G-layer shrinkage/GS: not significant. The structure and composition of the G-layer itself does not vary when GS increases but only G-layer thicknesses increases.

•Total cell wall shrinkage/GS: not significant, but related significantly with G-layer shrinkage. High proportion of G-layer in the cell wall can explain this phenomenon.

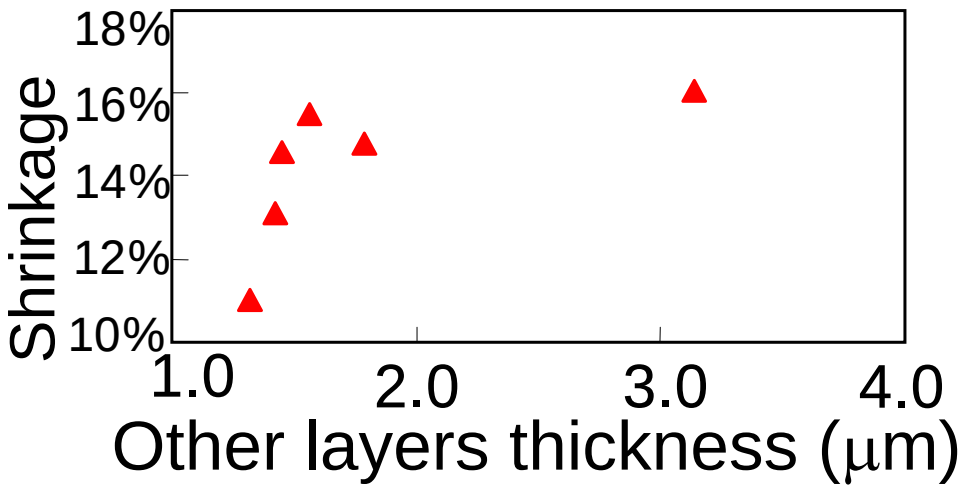
•The shrinkage of the OL had a very significant negative correlation with GS.

Shrinkage at microscopic level



Proportion in Other layers

- S_2+S_1 (Major role for other layers shrinkage): Decrease
- CL (Very low shrinkage (high lignified)): Increase



Shrinkage at microscopic level

Results and discussion

Correlations between parameters for the 5 samples with G-fibres except for the values marked with underline, which includes all the 6 samples. Correlation coefficients (Pearson) are given in the lower left half of the matrix and significance levels (2-tailed) in the upper right.

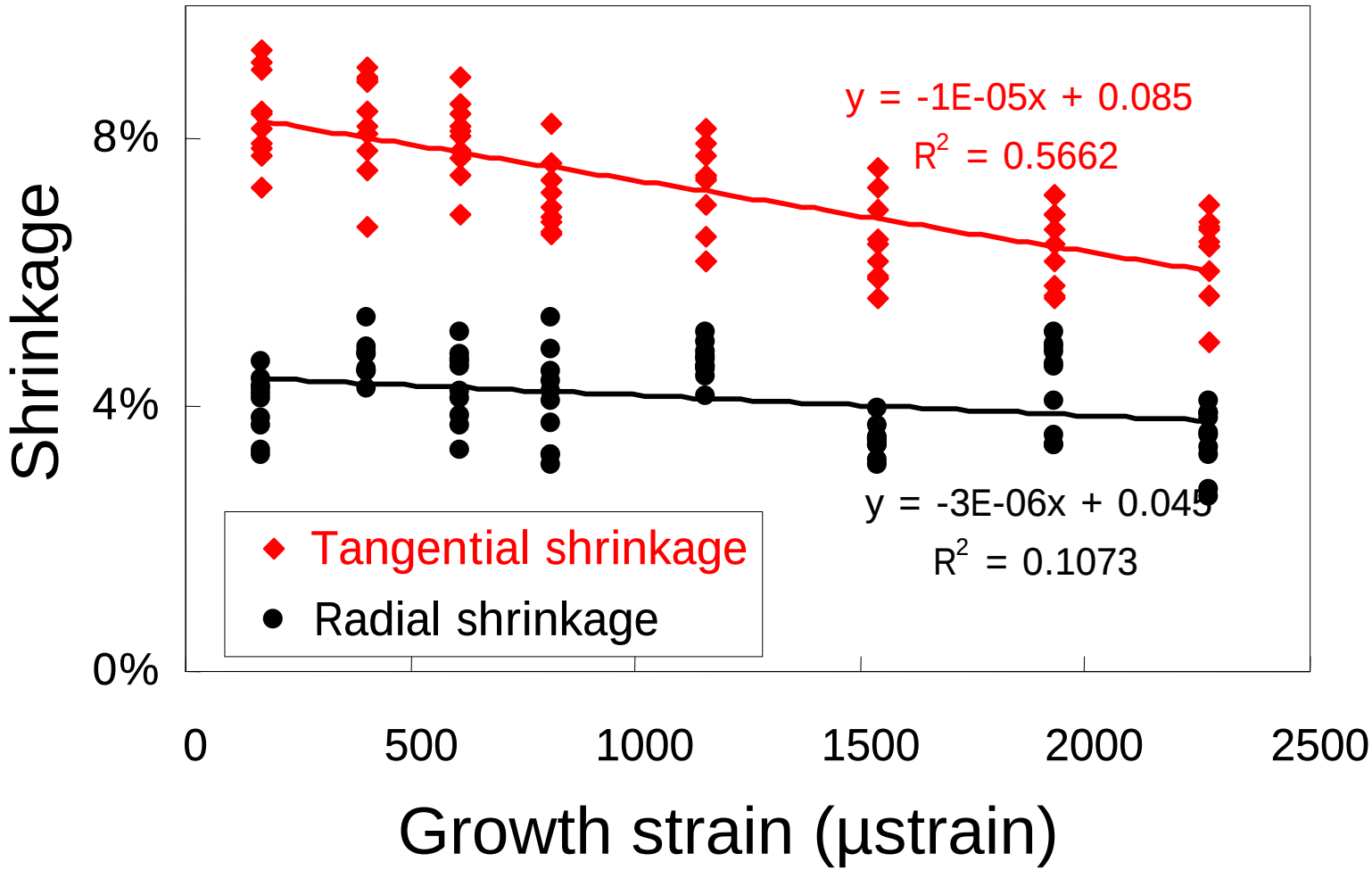
				(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Growth strain (με)			(1)	1	**	**	NS	**	**	NS	NS	**	NS
Thickness (μm)	Wet	G-layer	(2)	0.58	1	**	**	**	**	NS	NS	*	NS
		Other layers	(3)	-0.53	-0.42	1	**	NS	**	NS	NS	NS	*
		Total cell Wall	(4)	0.05	0.55	0.53	1	NS	NS	*	NS	NS	*
	Dry	G-layer	(5)	0.35	0.26	-0.08	0.17	1	NS	**	NS	*	NS
		Other layers	(6)	-0.47	-0.24	0.31	0.06	-0.17	1	**	NS	NS	*
		Total cell Wall	(7)	0.01	0.07	0.13	0.19	0.77	0.49	1	NS	NS	NS
Shrinkage (%)		G-layer	(8)	0.57	0.71	-0.50	0.48	0.57	-0.43	0.18	1	NS	*
		Other layers	(9)	-0.92	-0.96	0.63	-0.62	-0.93	0.61	-0.60	-0.70	1	NS
		Total cell wall	(10)	0.64	0.46	-0.87	0.83	0.32	-0.87	0.77	0.89	-0.59	1

NS = not significant, * = significant at 0.05 level, ** = significant at 0.01 level.

Shrinkage at mesoscopic level

Results and discussion

Tangential and radial shrinkages -- Growth strain.



Shrinking model of normal and tension wood cell

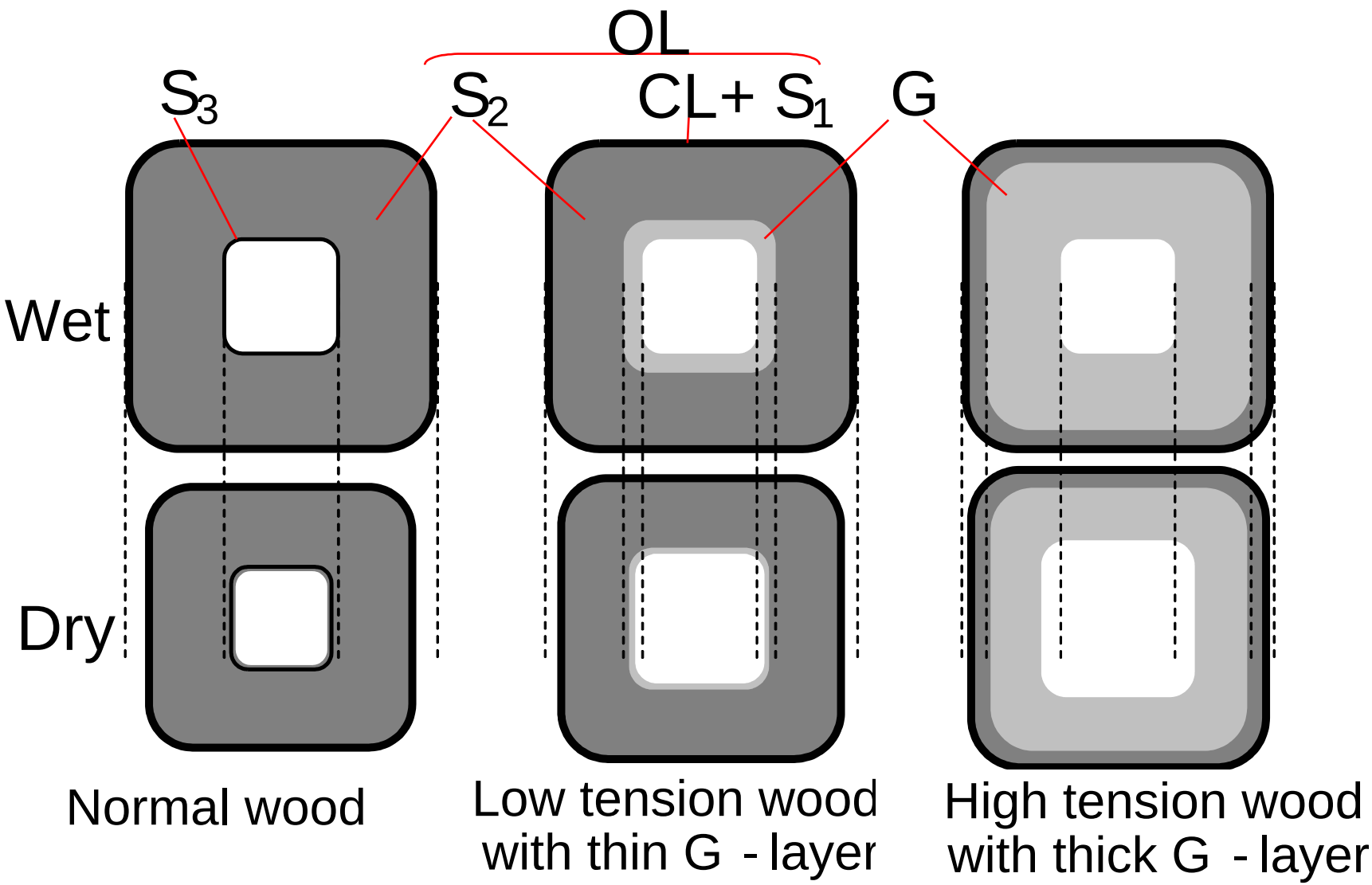
?:

Considering that the lumen diameter remain nearly constant during shrinkage as in normal wood (Keylwerth, 1951 and Kelsey, 1963), G-layer shrinkage being high, it should affect in the same way the mesoscopic shrinkage (cell wall shrinks from outer to inner during drying process). But, we found : the thicker the G-layer, the lower the transverse shrinkage.

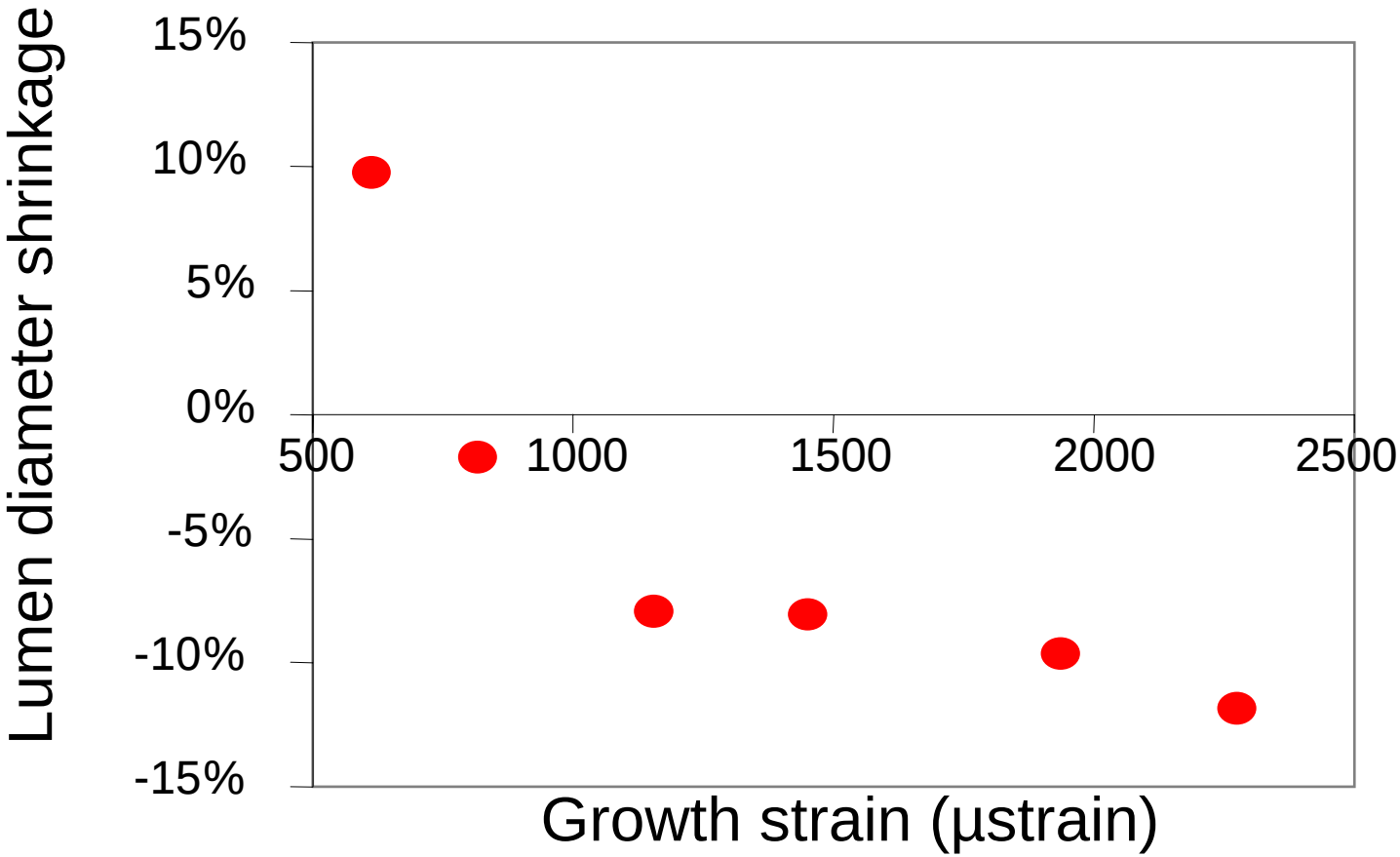
Supposition:

In tension wood, because of the absence of the S_3 layer, the G-layer shrinks from inner side to outer side during drying process. Thus, G-layer shrinkage feebly affects the total cell shrinkage. This means that the mesoscopic shrinkage is controlled by the OL shrinkage. OL shrinkage is essentially influenced by the secondary wall shrinkage: the higher GS, the thinner the secondary wall and the lower the transverse shrinkage.

Shrinking model of normal and tension wood cell



Shrinking model of normal and tension wood cell



Conclusion

- The thickness of normal wood cell wall was notably less than that of the tension wood cell wall including G-layer but markedly bigger than that of the other layers excluding G-layer. In tension wood the thickness of G-layer increased with GS and the thickness of the other layers decreased with GS.
- The dry shrinkage of G-layer was significantly higher than that of the other layers. There were not significant correlations between GS and the shrinkages of G-layer and total cell. But the other layers shrinkage negatively correlated significantly with GS.
- Section tangential dry shrinkage notably higher than radial one both in normal and tension wood. Section tangential shrinkage had a significant negative correlation with GS and radial shrinkage weakly negatively correlated with GS.
- G-layer, because it did not affect the shrinkage of total cell, shrinked from inner side to outer side during drying process, while the other layers, which controlled the total cell shrinkage, shrinked in the contrary direction.

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Thank you

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安徽农业大学
1935
Anhui Agricultural University

Shrinkage at microscopic level