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Composition dependence and implications

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Plastic deformation in glasses: Composition dependence and implications

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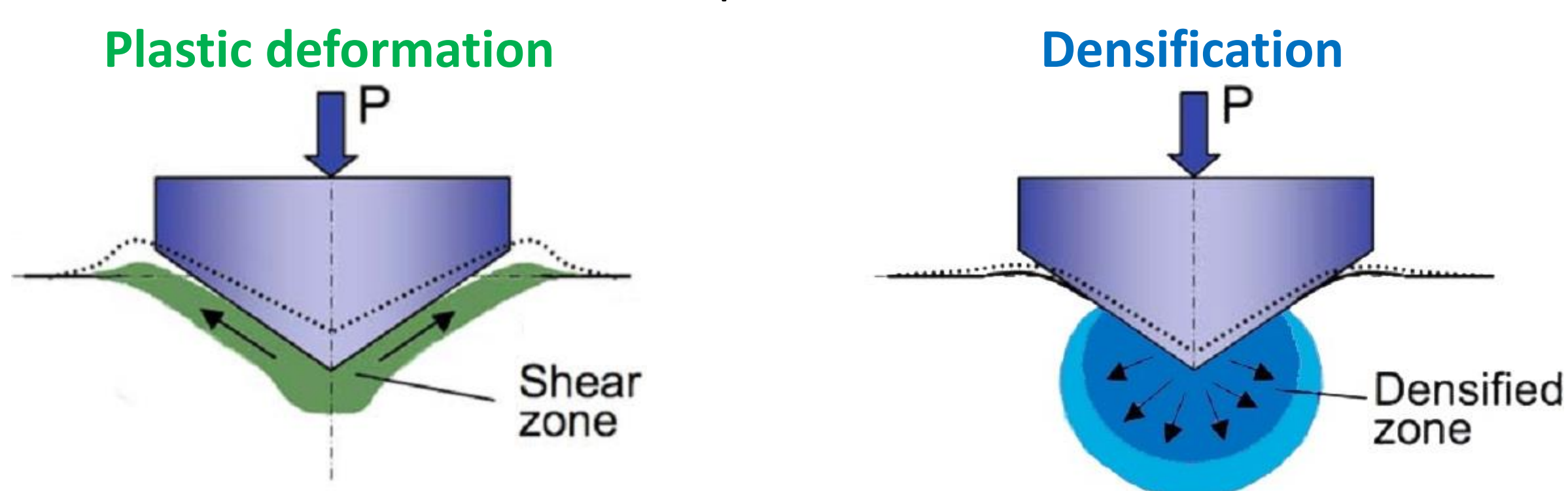
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Introduction

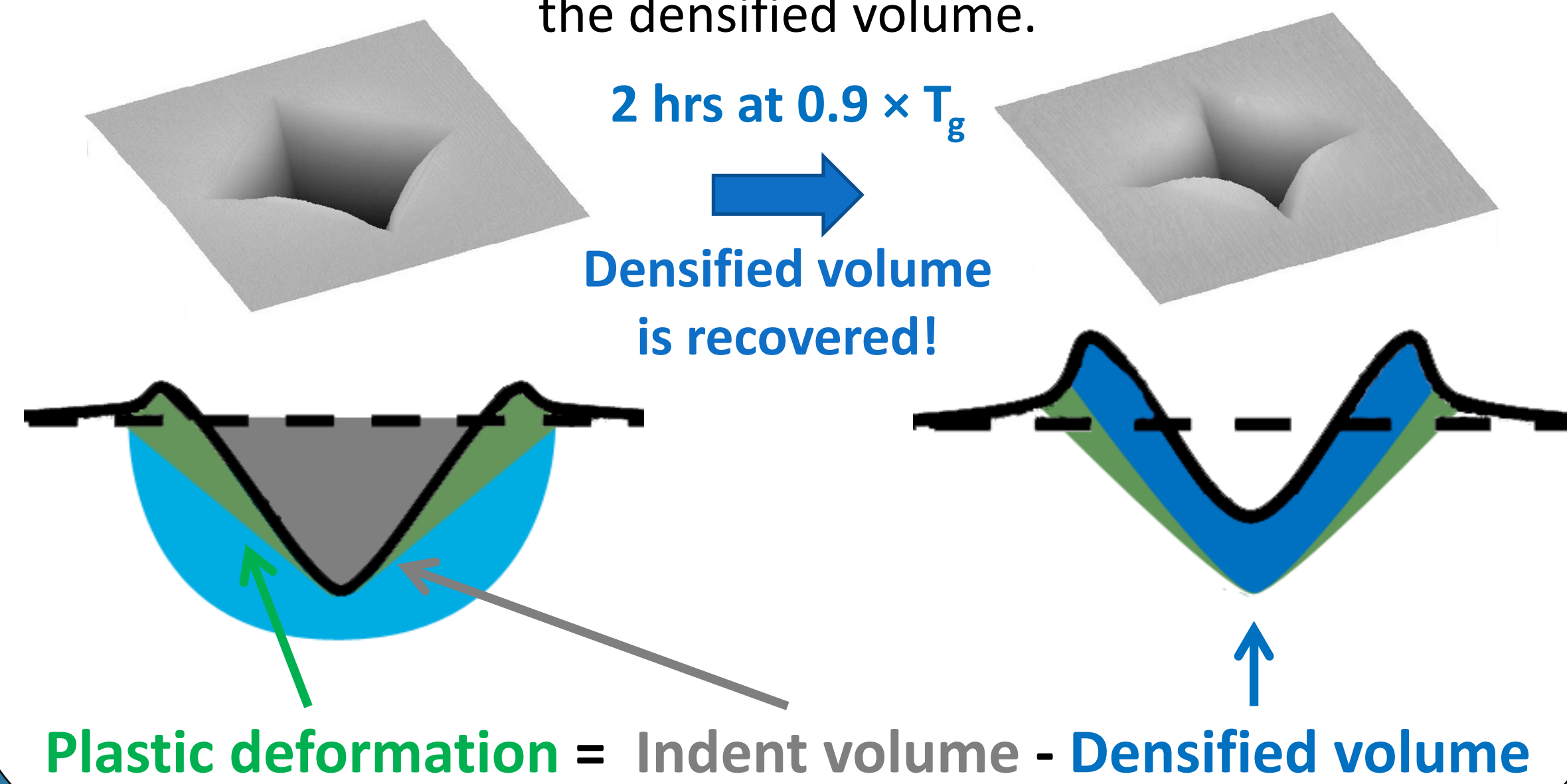
Although glass is considered an ideally brittle solid, permanent deformation will occur under gigapascal range shear as evidenced by microindentation studies. This work aims to quantify the two contributions to permanent deformation: Plastic deformation and densification.

Method

Step 1: The glass is indented, and plastic deformation and densification cause permanent deformation.



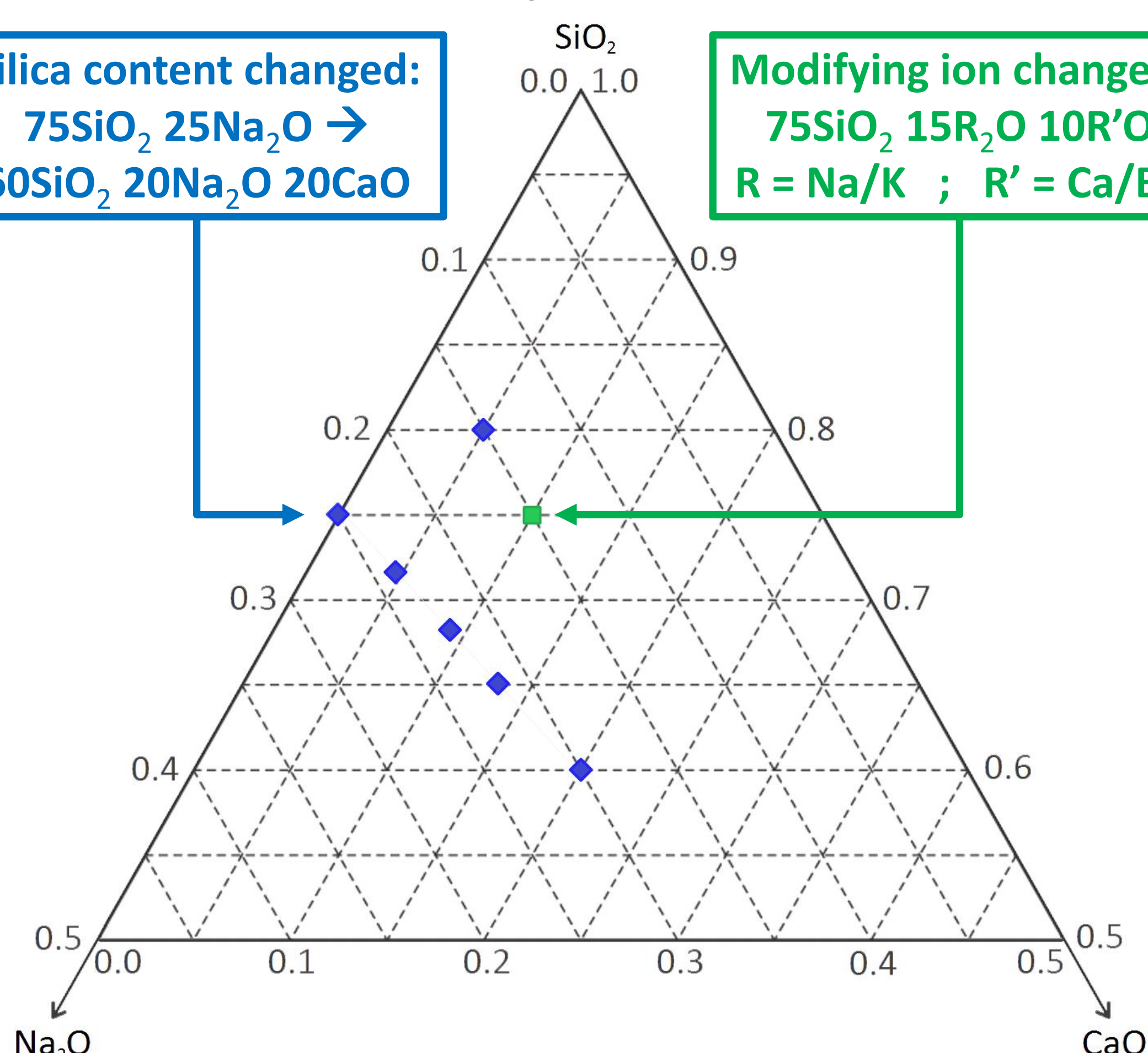
Step 2: The indent is mapped by AFM before and after annealing at $0.9 \times T_g$ for 2 hours. The annealing fully recovers the densified volume.



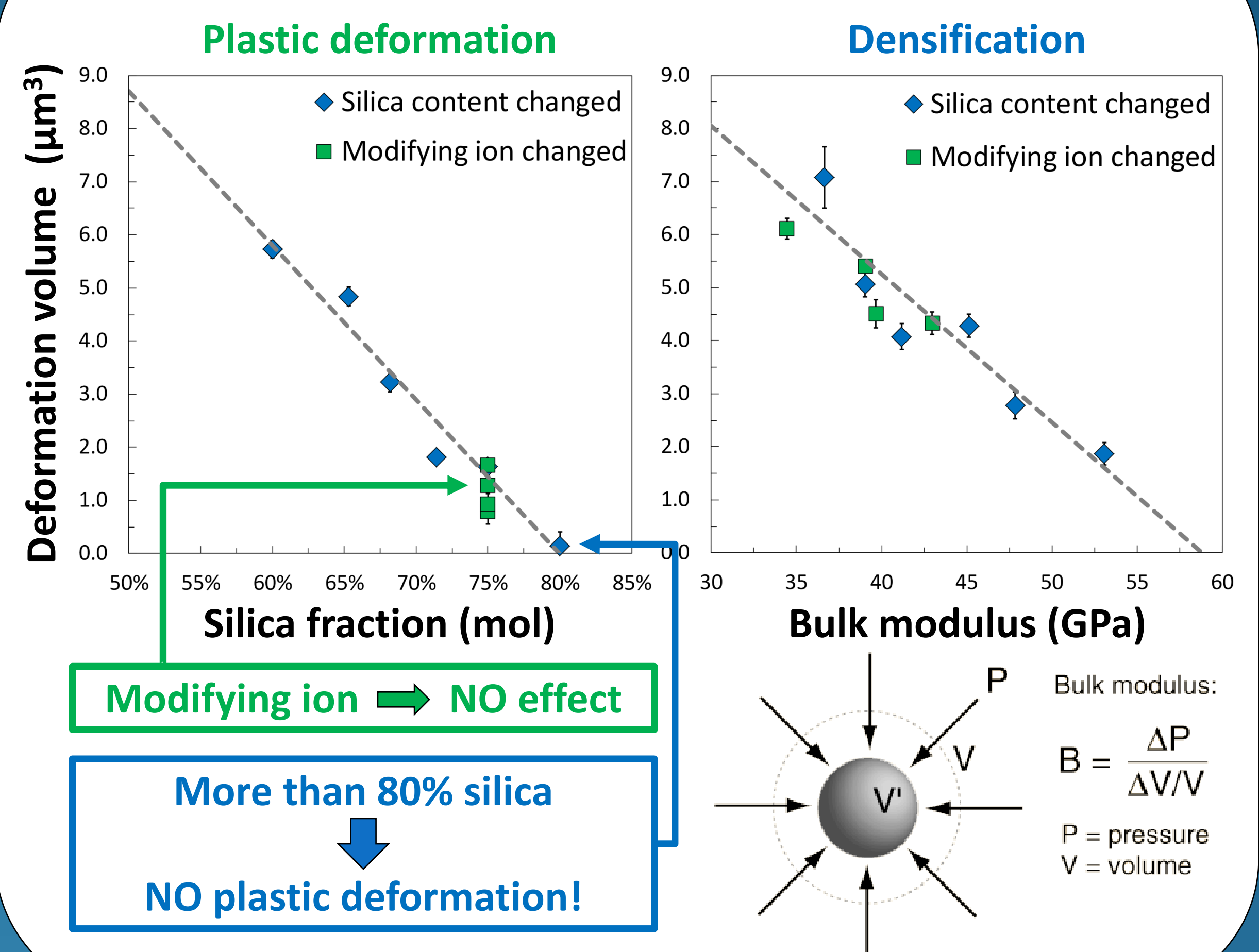
Compositions

Silica content changed:
75SiO₂ 25Na₂O →
60SiO₂ 20Na₂O 20CaO

Modifying ion changed:
75SiO₂ 15R₂O 10R'O
R = Na/K ; R' = Ca/Ba



Results



Discussion

Plastic deformation

- Negligible effect of modifying ion
- Decreases linearly with silica mole fraction
- No plastic deformation above 80mol% silica

Interpretation:

Depolymerization beyond a critical value (80% silica) allows for plastic deformation.

Densification

- Decreases linearly with bulk modulus

Interpretation:

A densificative yield pressure.

Conclusion

For the first time strong quantitative relations of plastic deformation and densification to other properties of glasses have been found. This result is expected to lead to the development of glasses with improved scratch and fracture resistance.