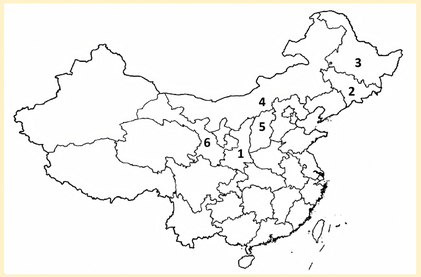
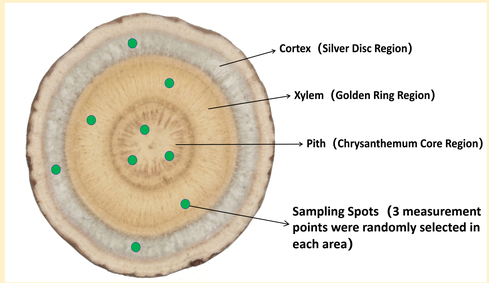
1.Source of the Sample & Anatomical Sampling

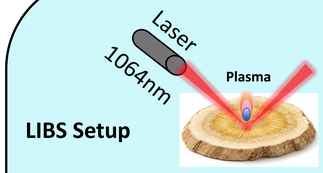


Six Producing Regions
(30 samples per region)
1.Shaanxi 2.Heilongjiang
3.Jilin 4.Inner Mongolia
5.Shanxi 6.Gansu



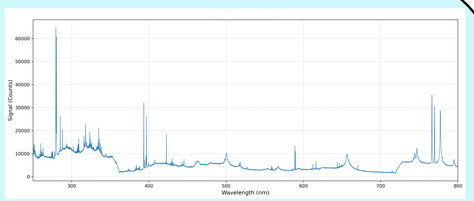
Rapid,**In Situ** Analysis Directly on Cross Section, **No Grinding or Pelletizing**

2.Data Acquisition & Spectroscopic Analysis

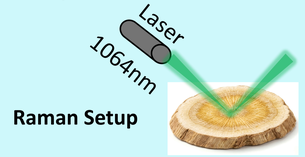


LIBS Setup

8100
LIBS Spectrum
250-800nm

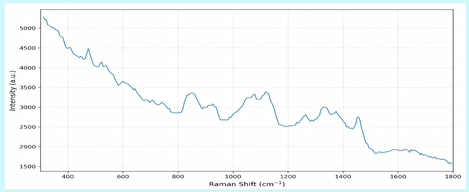


7 measurements per point
(2 clean sweeps and 5 measurements)
5 spectra were obtained for each point



Raman Setup

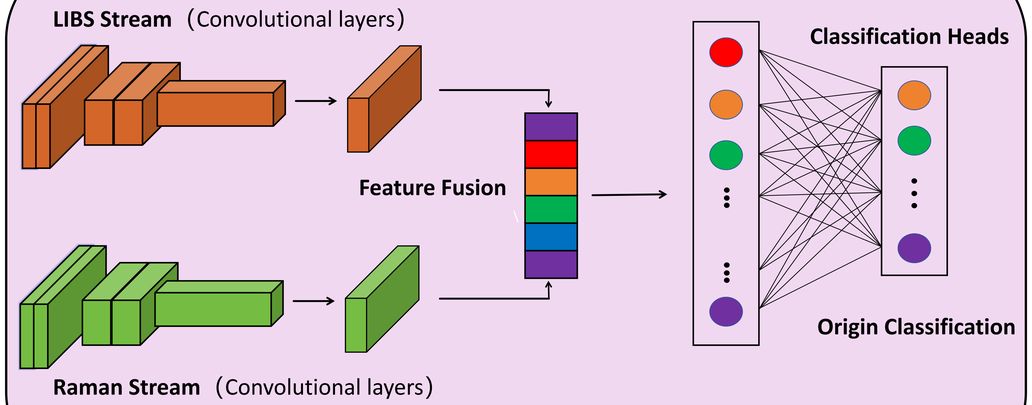
1620
Raman Spectrum
300-1800cm^{-1}



5 measurements per point and average
1 spectra were obtained for each point

3.Deep Learning & Data Fusion

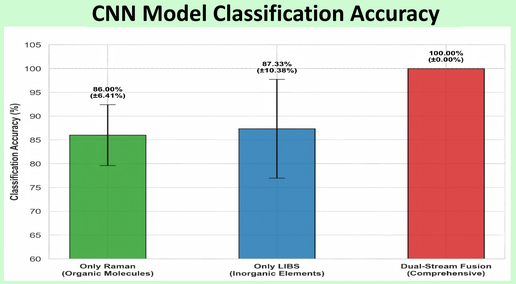
Dual-stream 1D-CNN architecture



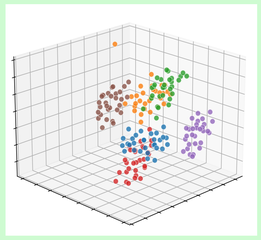
Retaining In-situ Hererogenetiity by Single-pulse LIBS Strategy

4.Results & Interpretation

CNN Model Classification Accuracy

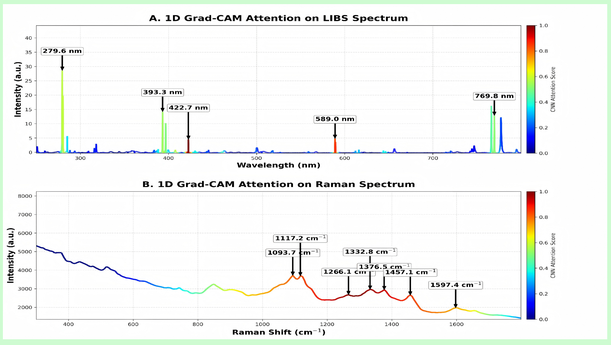


3D PCA Visualization of CNN Fused Features and Classification Clusters



Fused CNN model achieves 100% Accuracy (seed=42)

Grad-CAM interpretability



LIBS Key Discriminants: **Ca,Na,Mg,K**
Correlated to Source-specific
Mineral and Rhizosphere Conditions

Raman Key Discriminants:**Cellulose**, **Lignin**
Derived from Source-specific
Cell-wall Structural Organization

5.Conclusion

1.Paired LIBS and Raman spectroscopy enabled rapid traceability of intact Astragali Radix slices from six origins.

2.The dual-stream 1D-CNN preserved single-pulse information from 8100 unaveraged LIBS spectra and captured spatial heterogeneity.

3.LIBS–Raman fusion outperformed single-modality models and achieved 99.33% external-test accuracy.

4.Ca/Mg/Na/K LIBS lines and lignocellulose-related Raman bands were identified as key discriminative markers.