WRI Research Related to the Optimal Timing of Preventive Maintenance for Addressing Environmental Aging

Kickoff Meeting

Fred Turner

Western Research Institute

MnROAD Research Facility

July 23, 2008

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Relevant Research Contracts

- ✓ **Fundamental Properties of Asphalts and Modified Asphalts III,** *Federal Highway Administration*
- ✓ **Asphalt Surface Aging Prediction (ASAP) System,** *Research and Innovative Technology Administration*
- **Asphalt Research Consortium,** *Federal Highway Administration (Aging element, F1c, being conducted by TAMU)*

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FPIII Aging Research

- **Study aging in laboratory and field conditions**
- **Develop testing methods for analyzing aging**
- **Compare results with the Global Aging System as implemented in the MEPDG**

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Techniques Developed

- **Micro extraction with FTIR analysis**
- **Photoacoustic FTIR for surface analyses**
- **Small scale DSR methodology for full range modulus and relaxation rheology (in progress)**
- **Carbonyl index**
- **Non-carbonyl FTIR-G* correlations**
- **Spectral correlation software**

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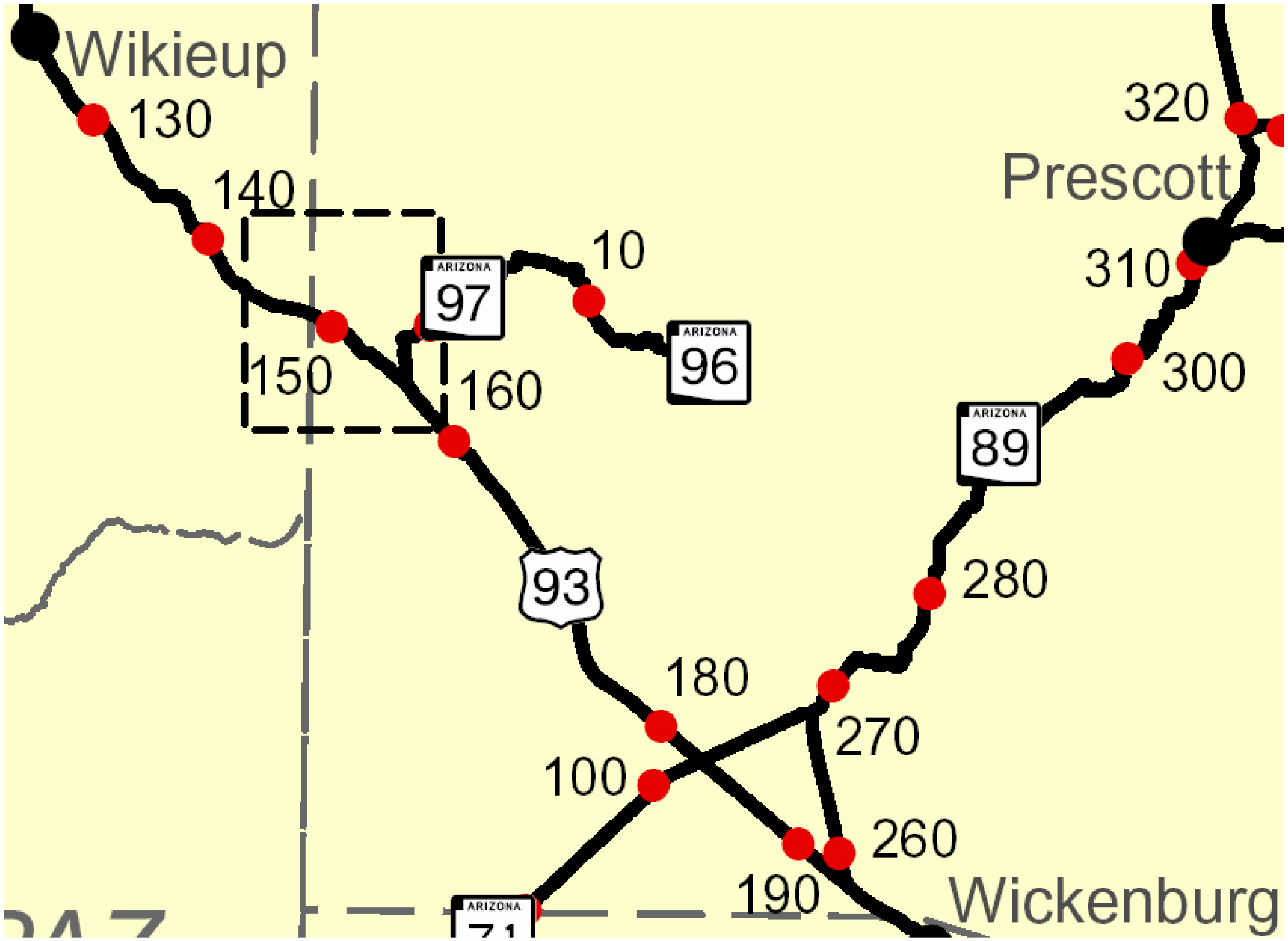
Aging at the Arizona Validation Site



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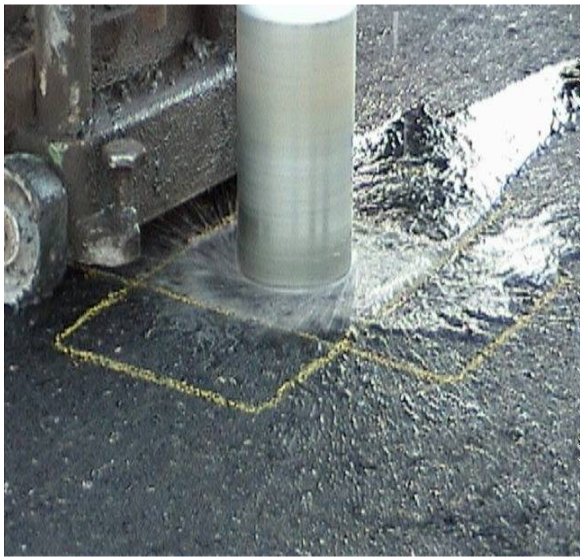
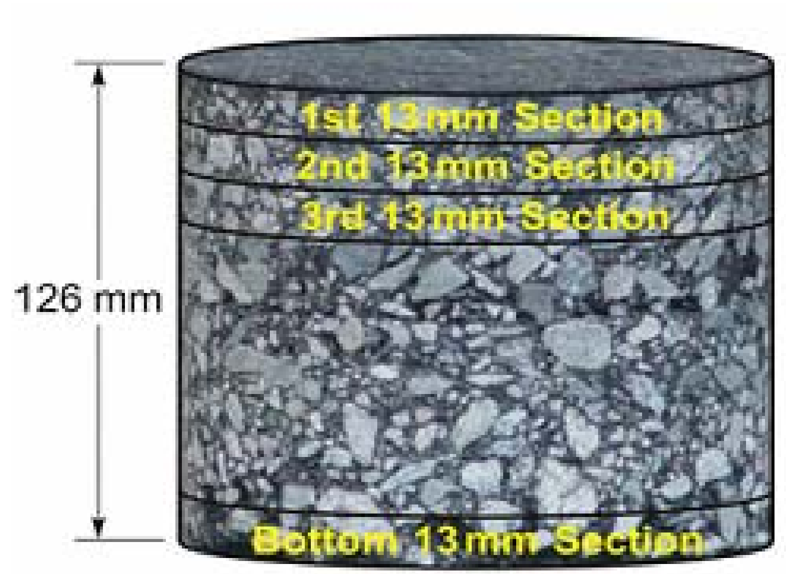
Arizona Validation Site





Constructed Nov. 2001
Shoulder cored Nov. 2005

2 – 63 mm lifts, 19-mm NMS dense graded aggregate, 4.7% AC)

Farrar, M. J., P. M. Harnsberger, K. P. Thomas, W. Wiser. Evaluation of Oxidation in Asphalt Pavement Test Sections after Four Years of Service. Proceedings of the International Conference on Perpetual Pavement, September, 2006, Columbus, Ohio.

Asphalt Hardening: Laboratory and Field Aging

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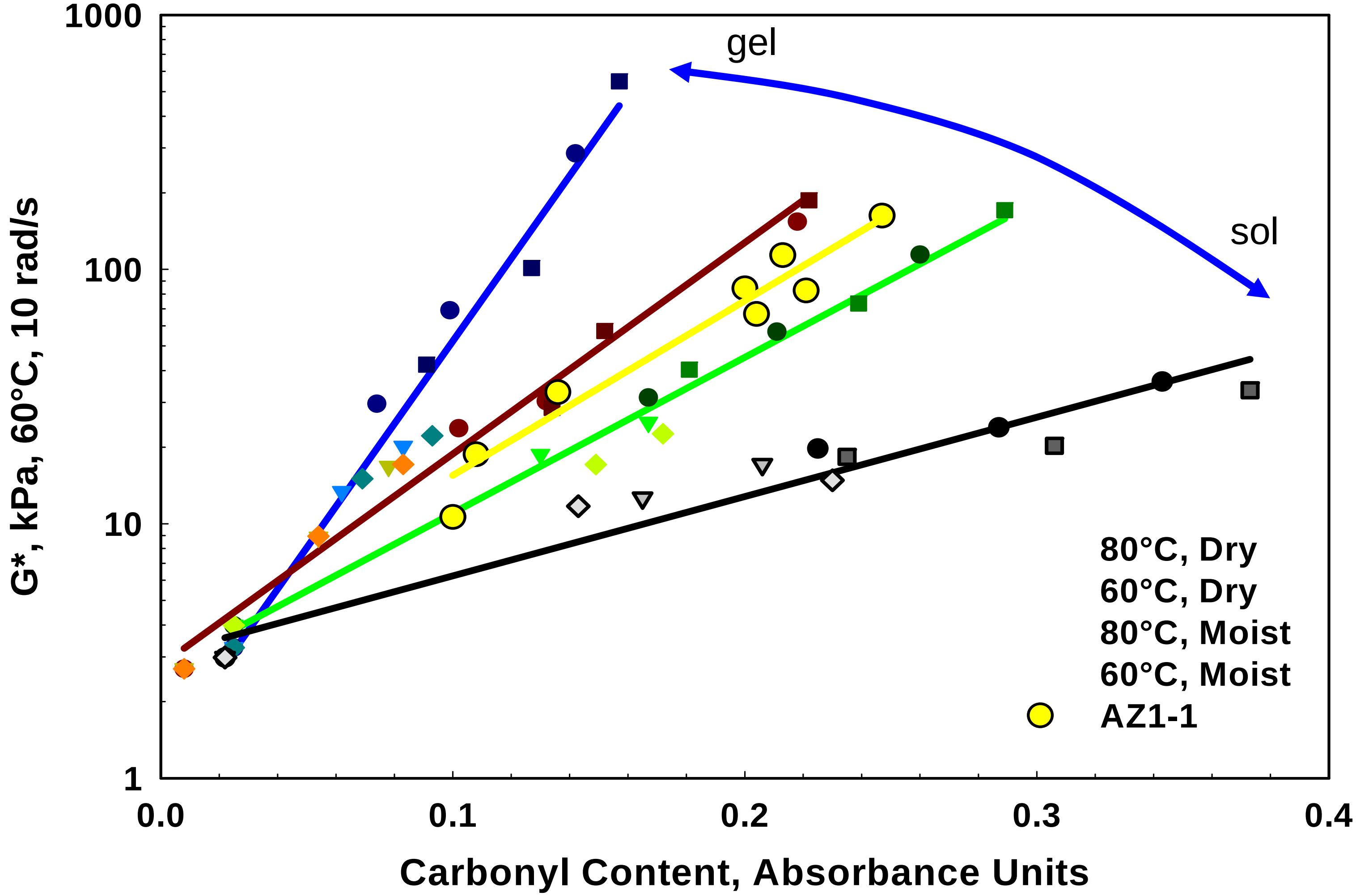
Relationship between carbonyl content and complex modulus of asphalts



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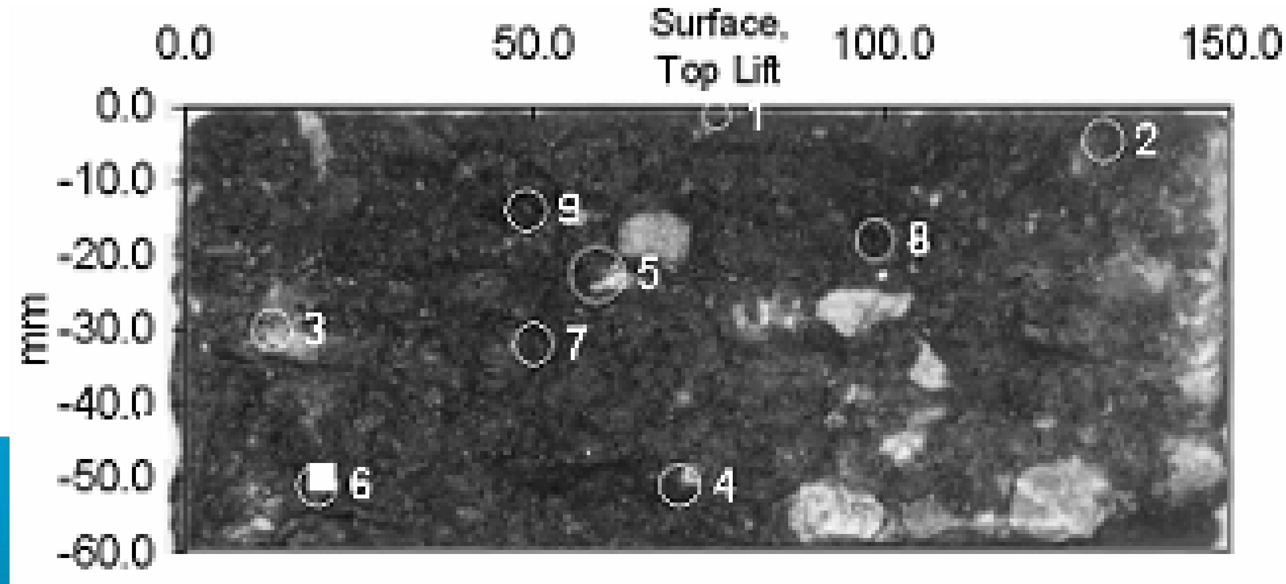
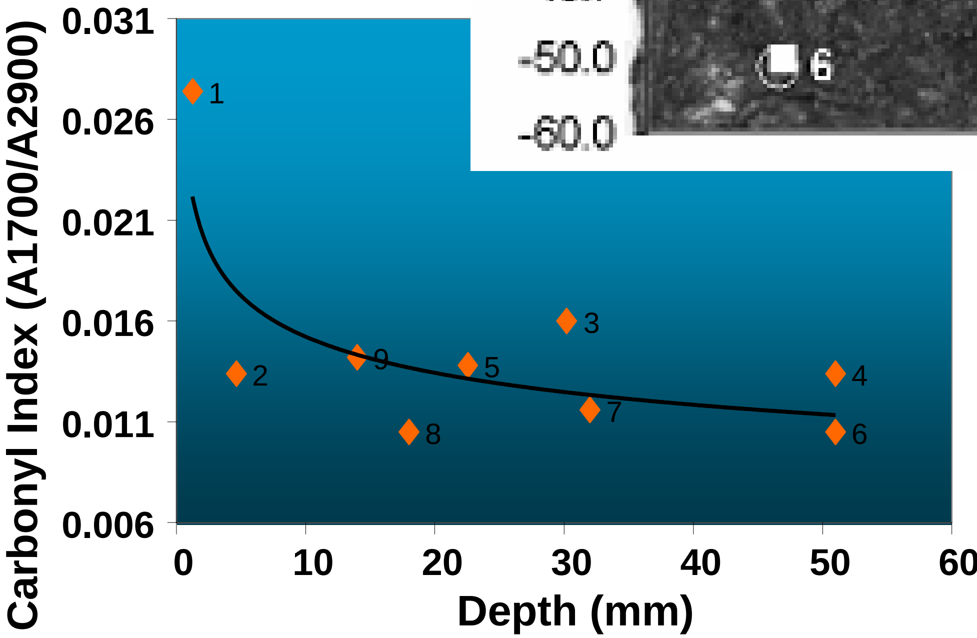
Arizona Site Aging Profile

Carbonyl Gradient AZ1-1





Linear relationship

Log G* vs. C=O

G* Gradient

Hirsch Model

E* Gradient

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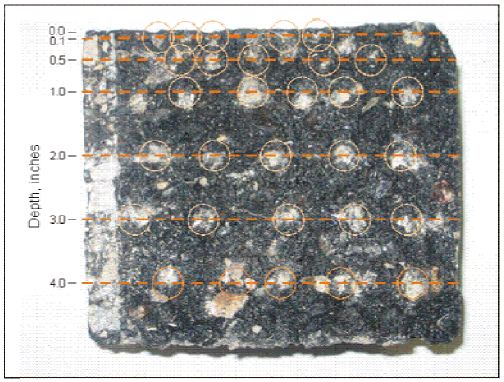
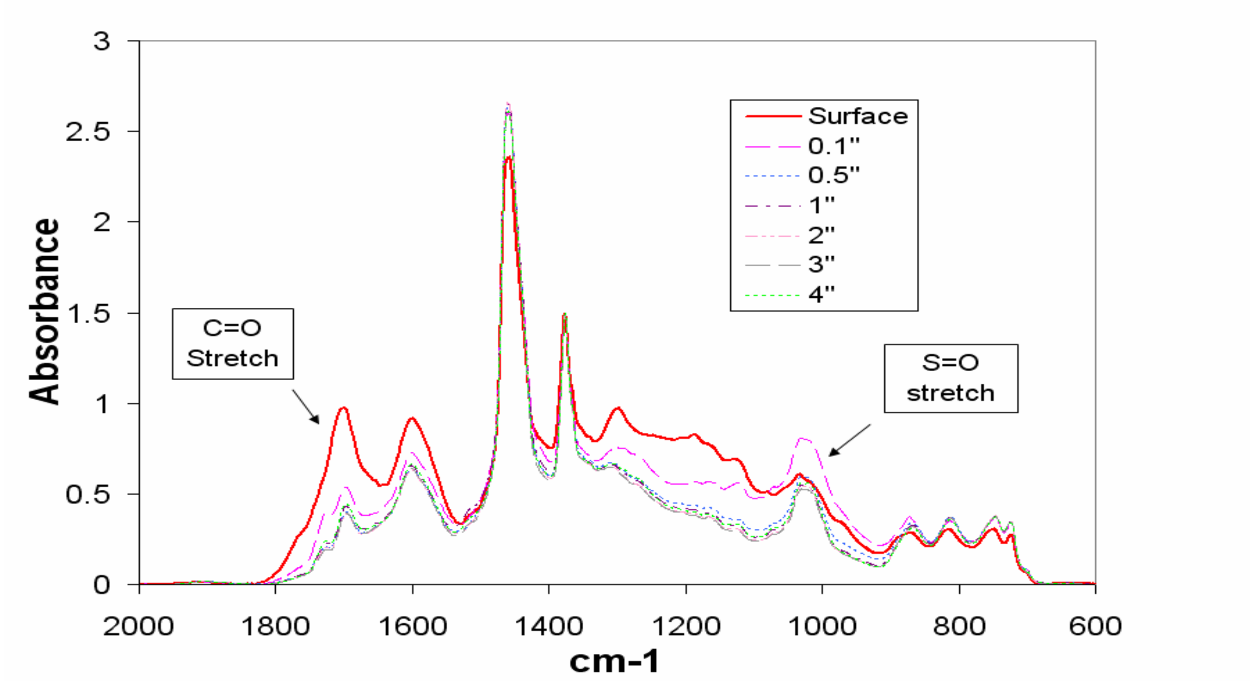
Infrared Spectra From Each Layer

AZ1-3b core



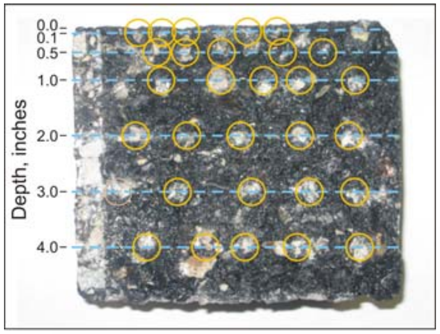


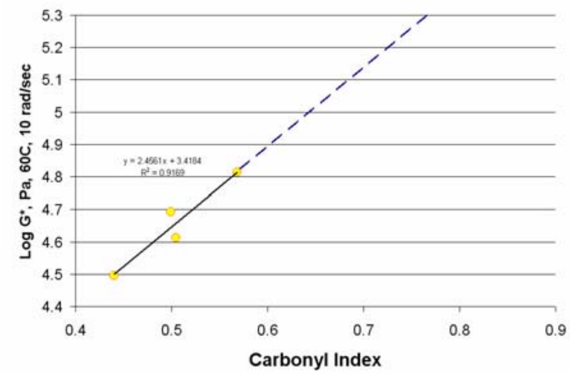
Spectra normalized to CH_3 umbrella bending mode at 1376 cm^{-1}

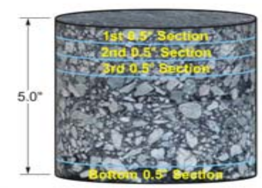
Carbonyl index
Sulfoxide index
Aromaticity index
Other indexes

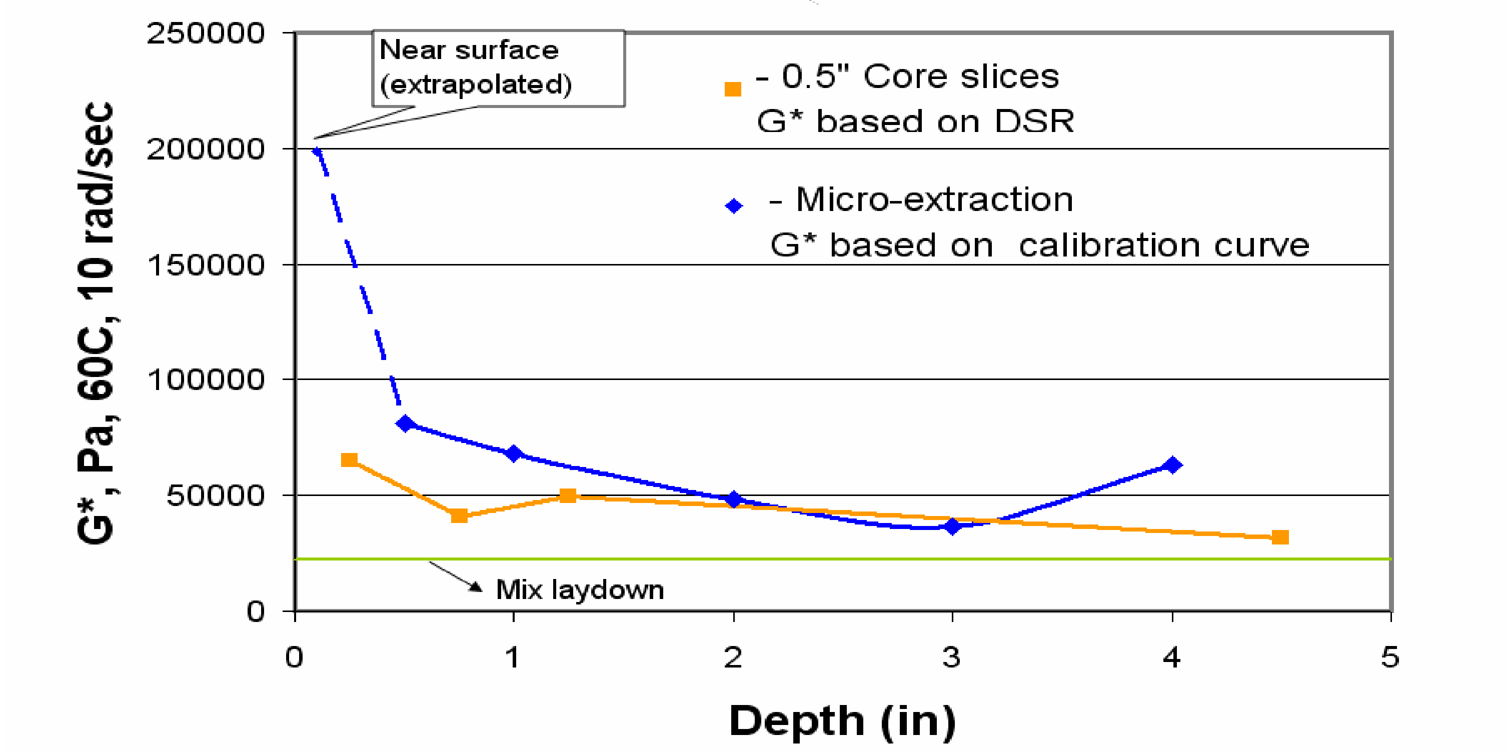
Functional group depth gradients

G gradient - Arizona validation site at year four*

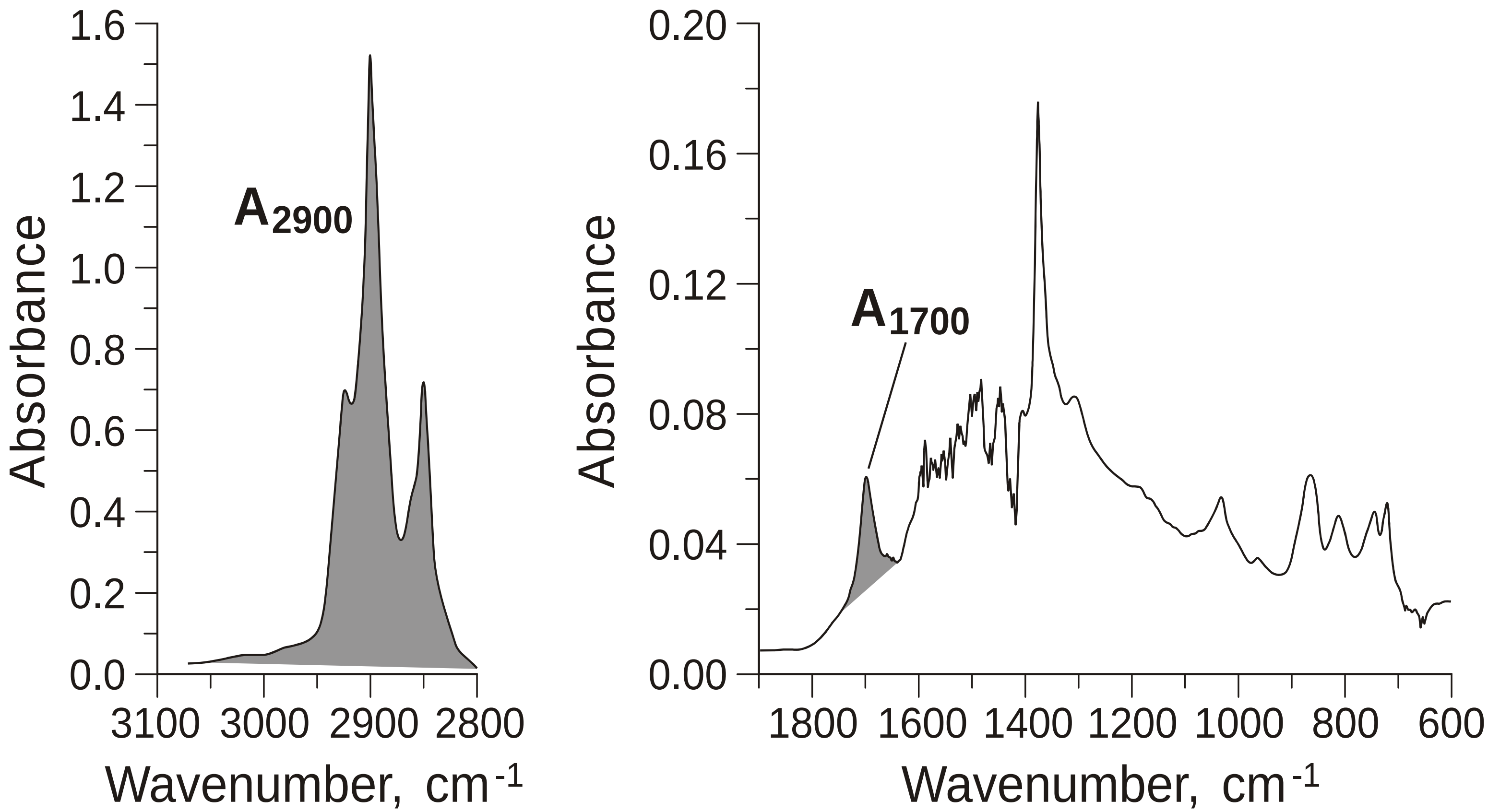








Carbonyl Index



$$\text{Carbonyl Index (CI)} = \frac{A_{1700}}{A_{2900}}$$

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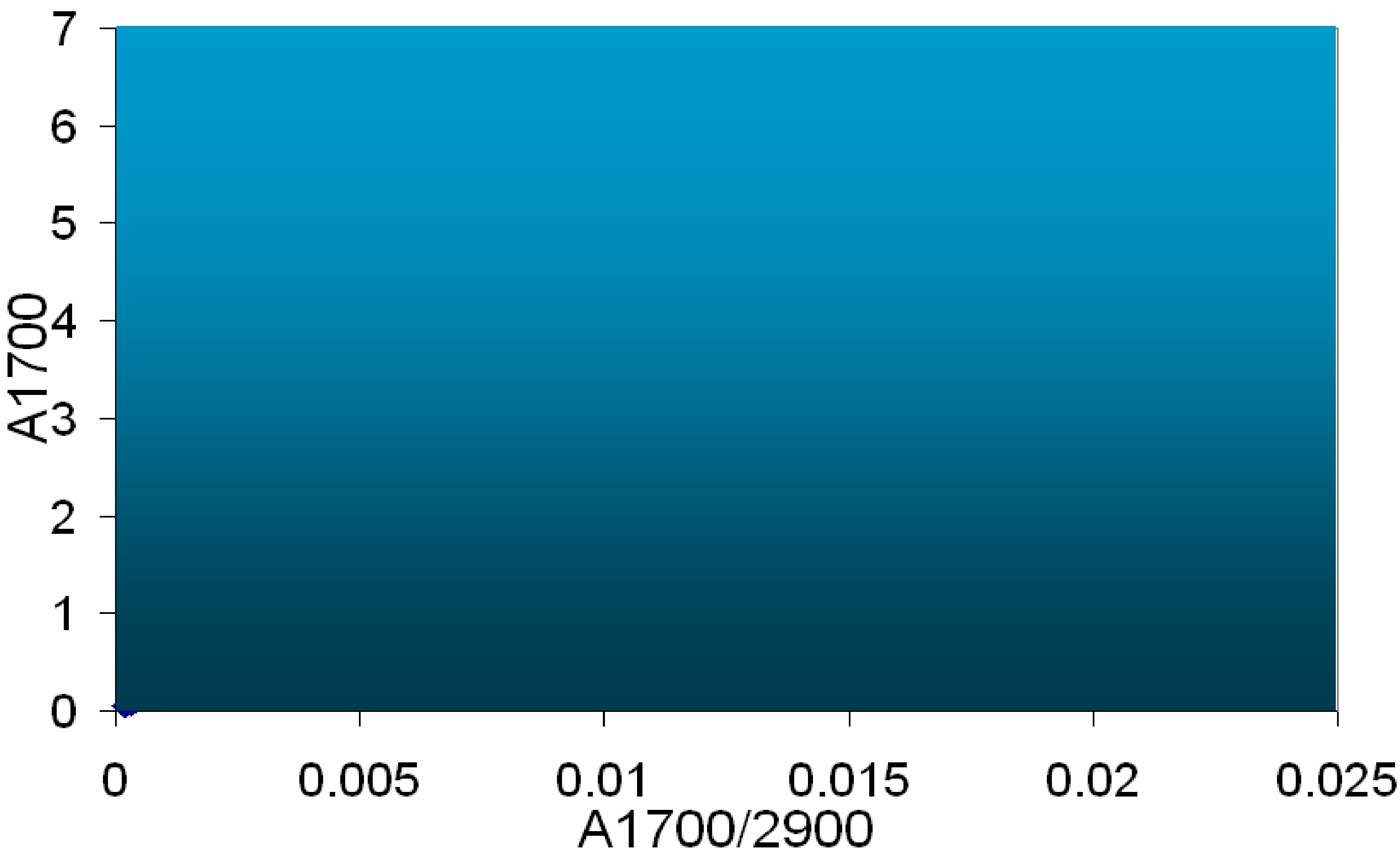
Carbonyl Index (8 asphalts)



- **Develop and demonstrate ruggedized FTIR instrumentation, data acquisition system, and data processing procedures to predict and monitor the surface embrittlement of asphalt pavements caused by aging**

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Techniques Applied

- **Micro extraction with FTIR analysis**
- **Photoacoustic FTIR for surface analyses**
- **Carbonyl index**
- **Non-carbonyl FTIR-G* correlations**

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Project Elements

Laboratory (WRI)

- Validate spectroscopy-rheology correlation
  - Find non-carbonyl relationship for airborne applications
- Prepare samples for calibrating ruggedized FTIR system
  - Unaged, RTFO-aged, RTFO/PAV-aged, field samples
- Develop procedures for handling real-world analyses:
  - Asphalt content < 100%,
  - Aggregate infrared absorption, contaminants
  - Carbonyl indexing
  - Aggregate and contaminant subtraction techniques

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Project Elements

Development of FTIR system (Innova, PLX, SimWright)

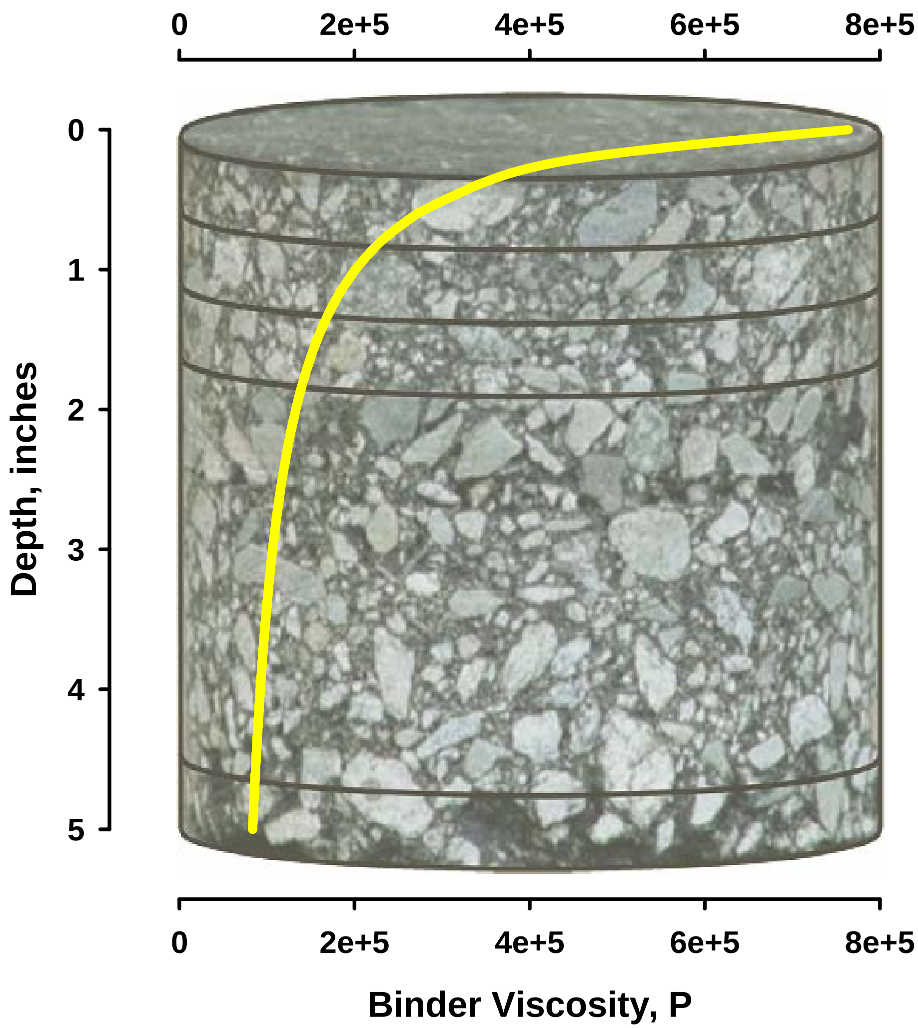
- **Design, construct, and test a vehicle-mounted ruggedized FTIR system**
- **Demonstrate the technology in the field using a van-mounted, non-contact system**
- **Determine the effective limits for low-altitude airborne deployment**

Age-Related Change at Surface

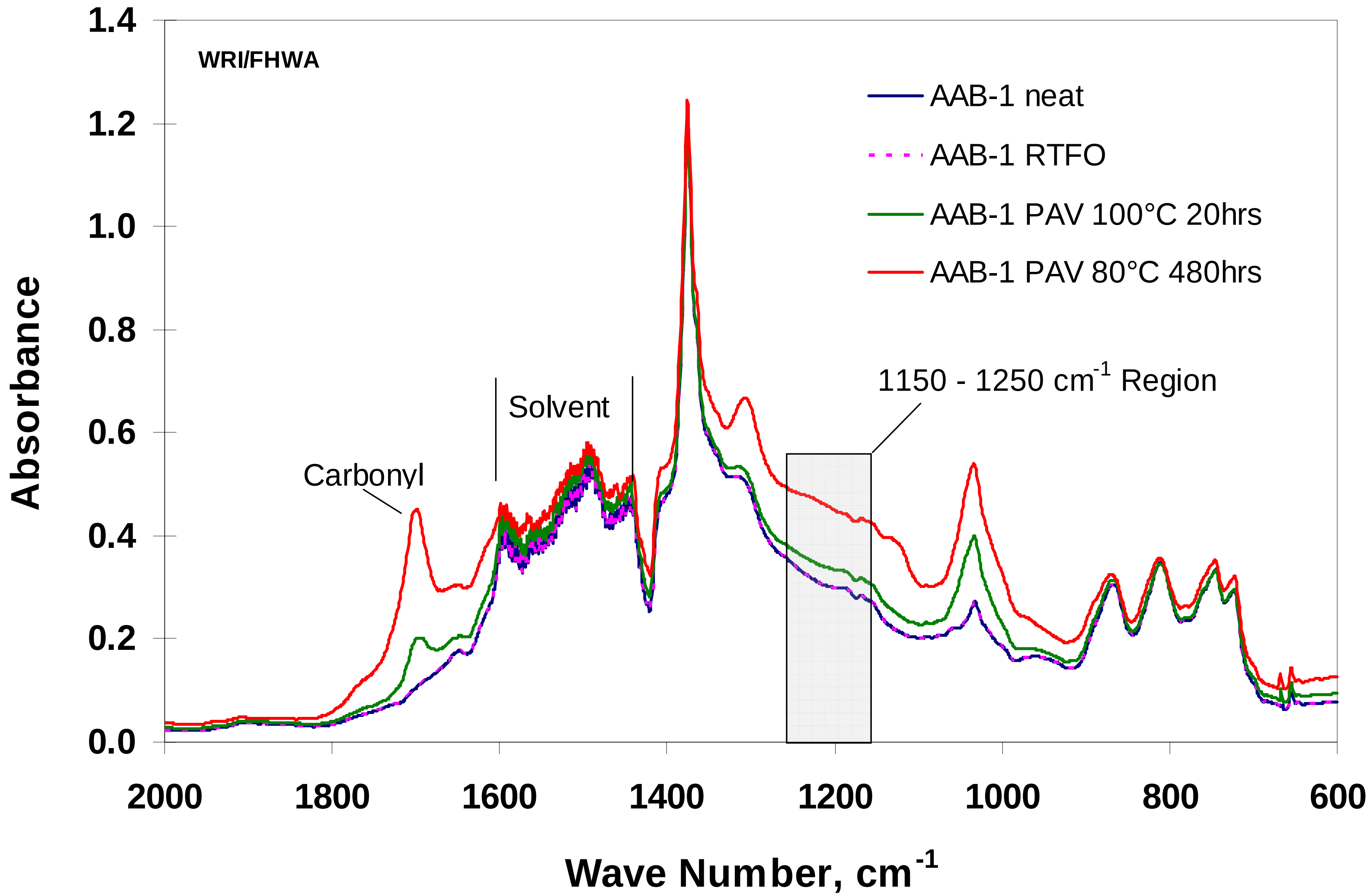
Observations and Assumptions

- **HMA pavements oxidize most rapidly at their top surfaces.**
- **The oxidized binder at the surface has a much higher stiffness than the bulk binder.**
- **The surface stiffness or complex modulus at lower ambient temperatures will approach the glassy modulus of the binder (~ 10^9 Pa).**
- **Pavement damage begins under traffic load when the surface complex modulus of the binder reaches some fraction of the glassy modulus at current use temperature.**

Az1-1 4-yr viscosity profile



Infrared Spectra Changes w/ Aging



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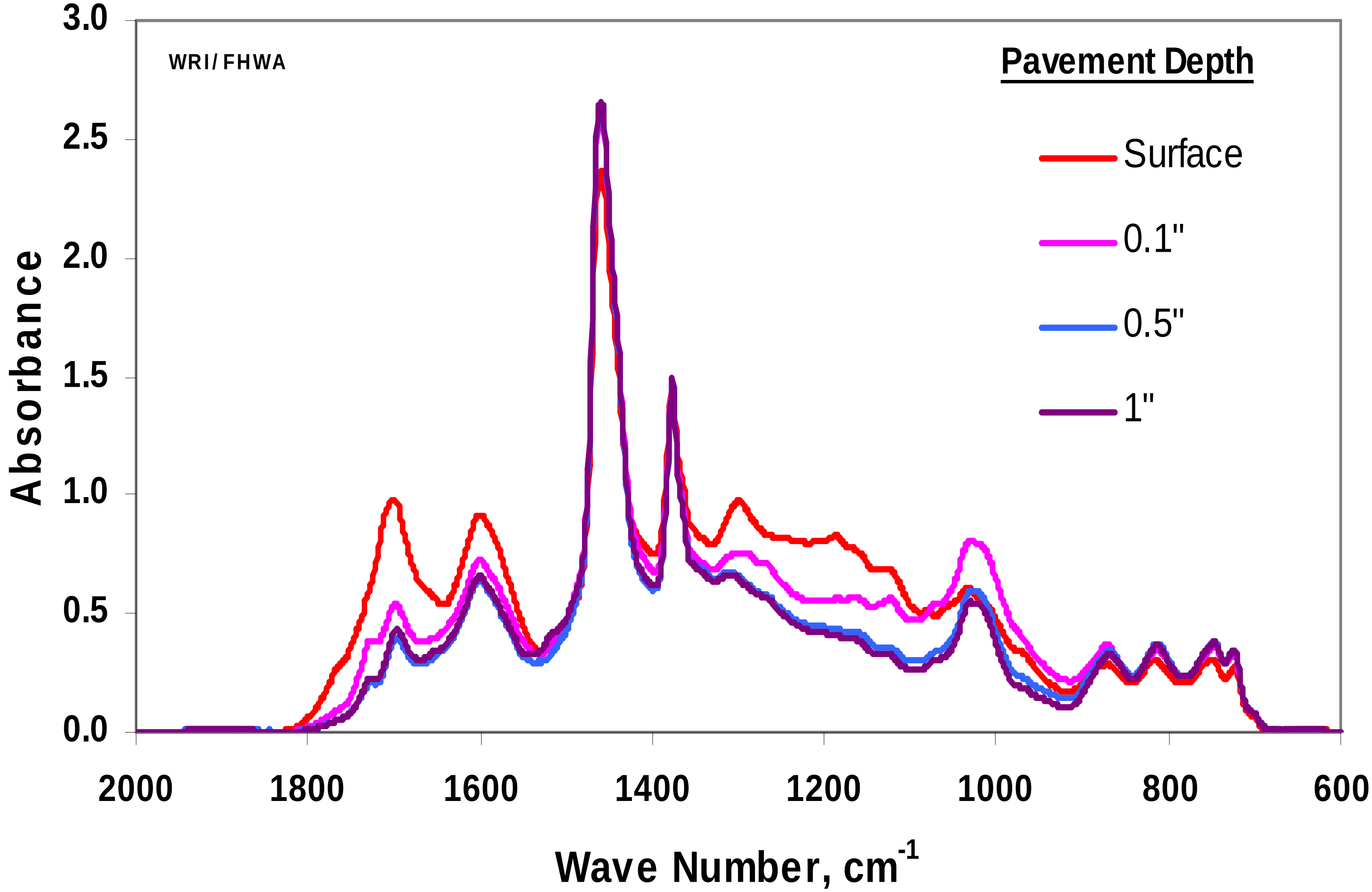
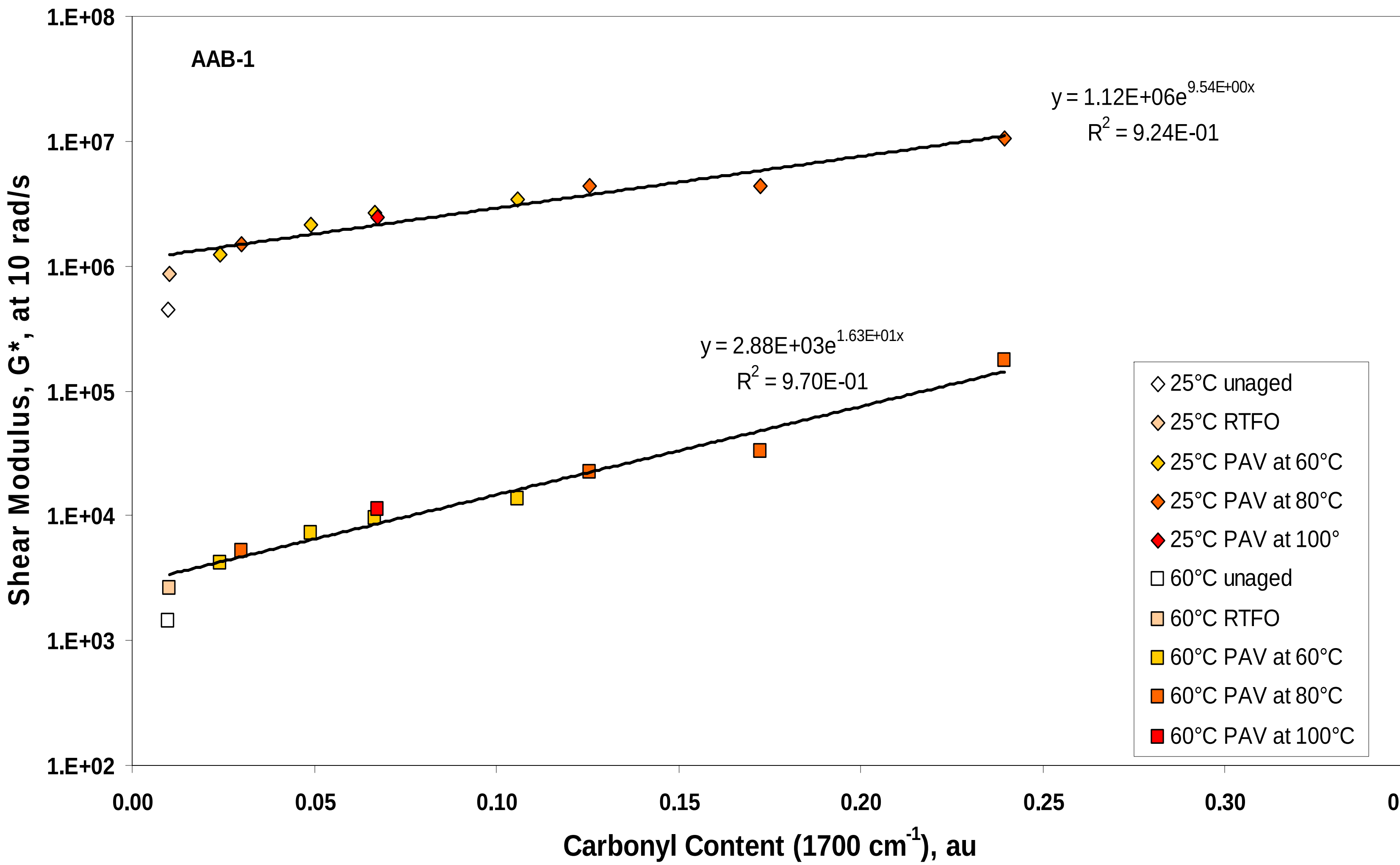
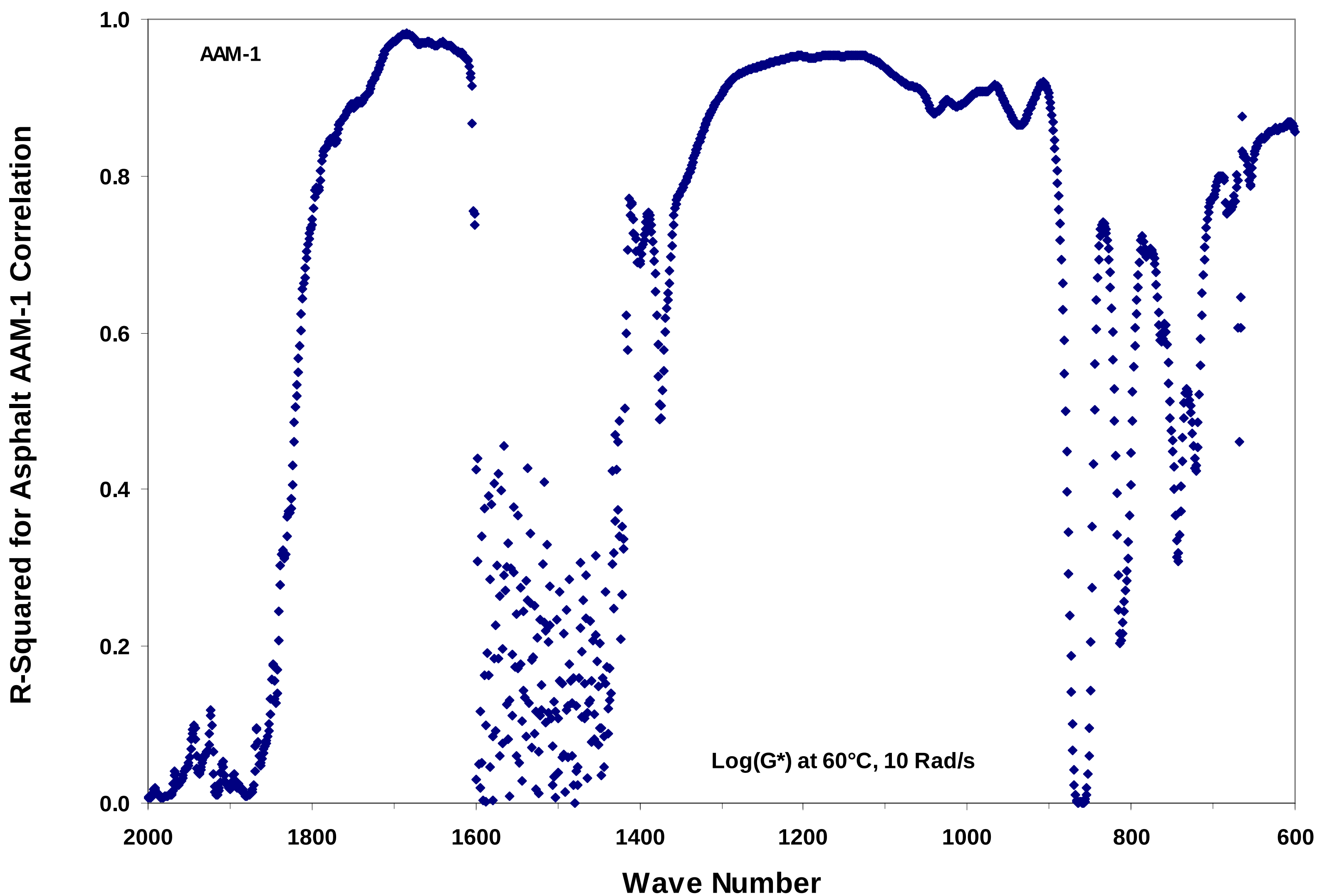
Infrared Spectra Changes w/ Depth



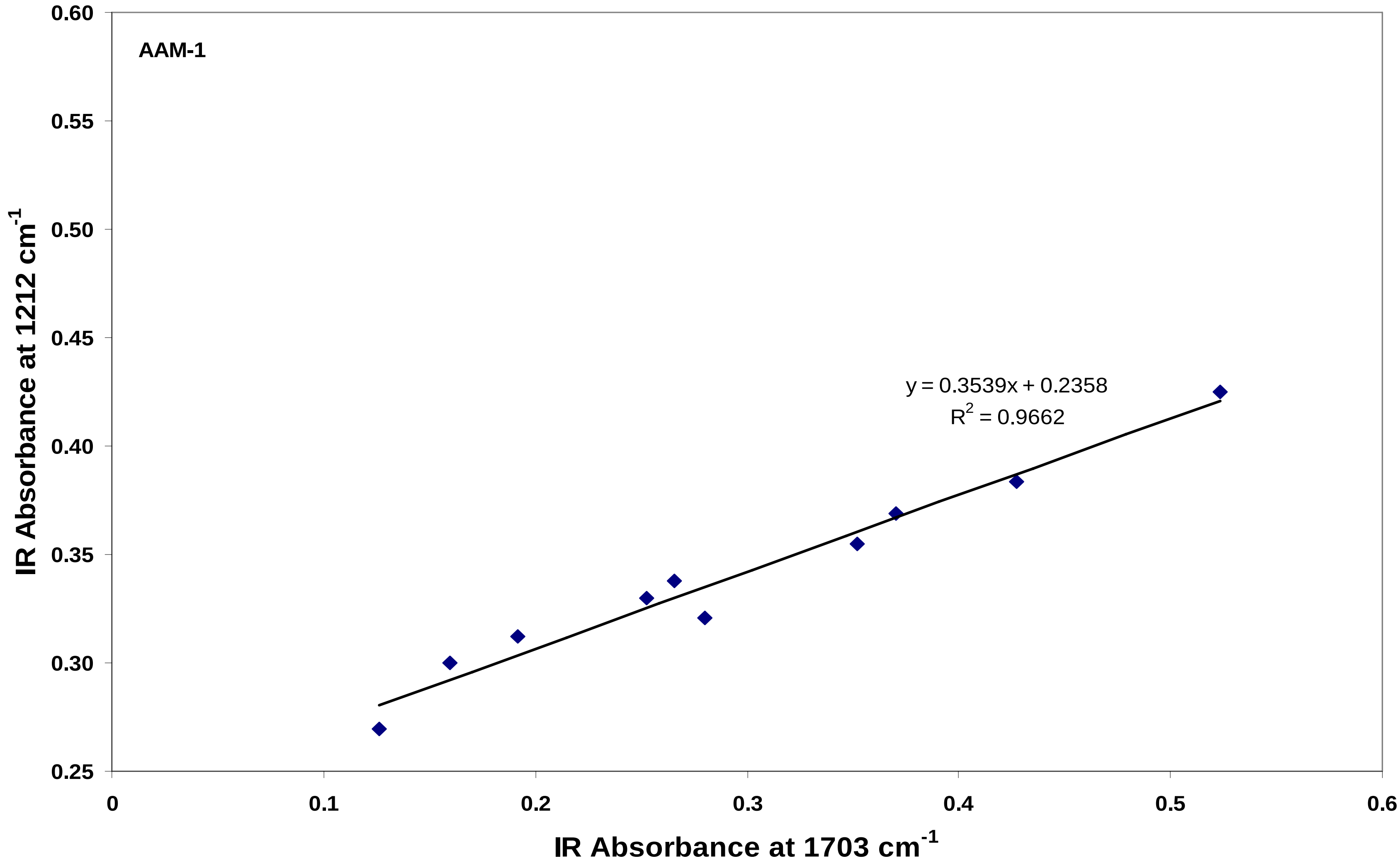
G* Correlations With Carbonyl Content For AAB-1



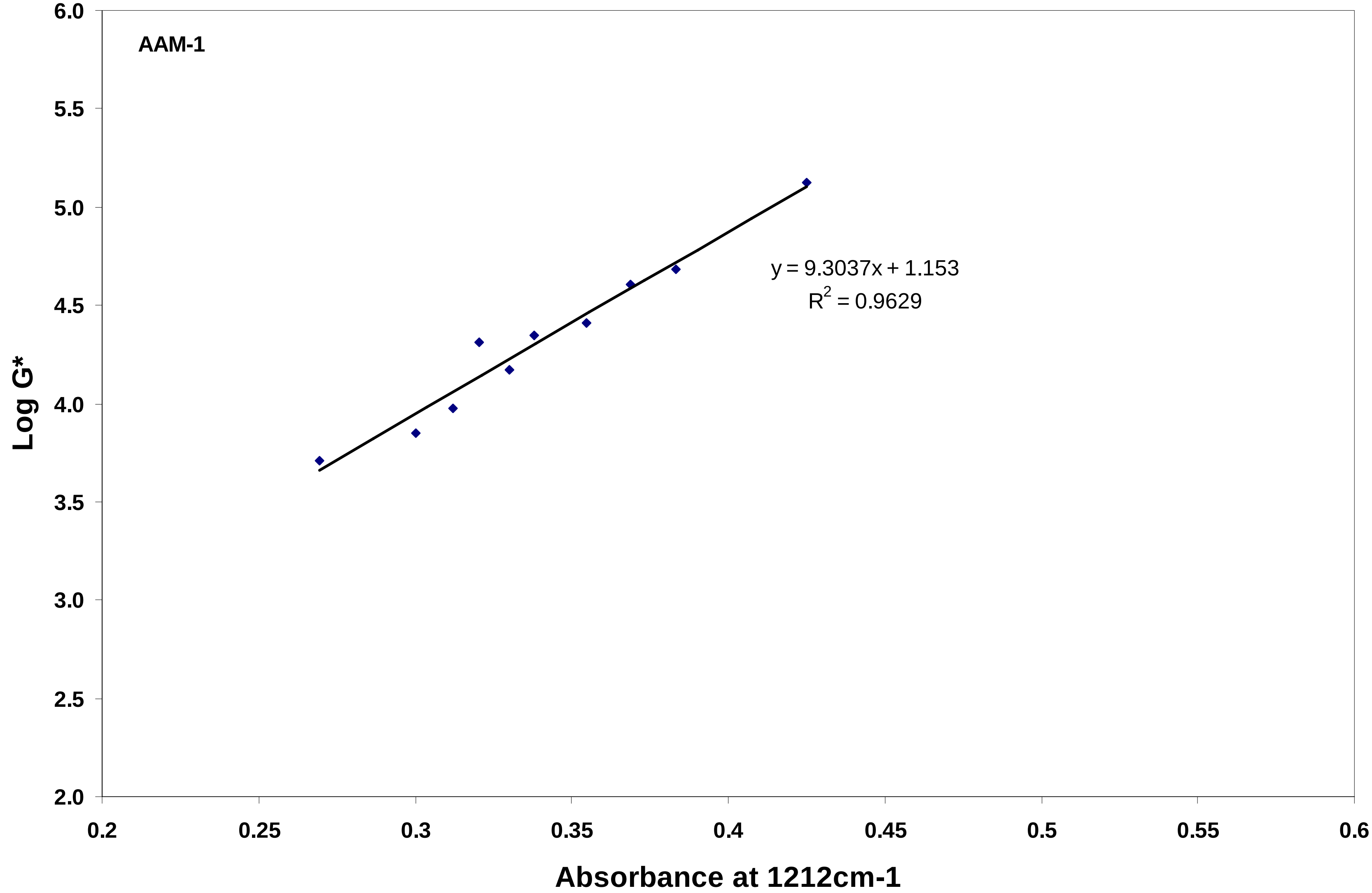
Analysis of Infrared Spectra for Correlating Regions



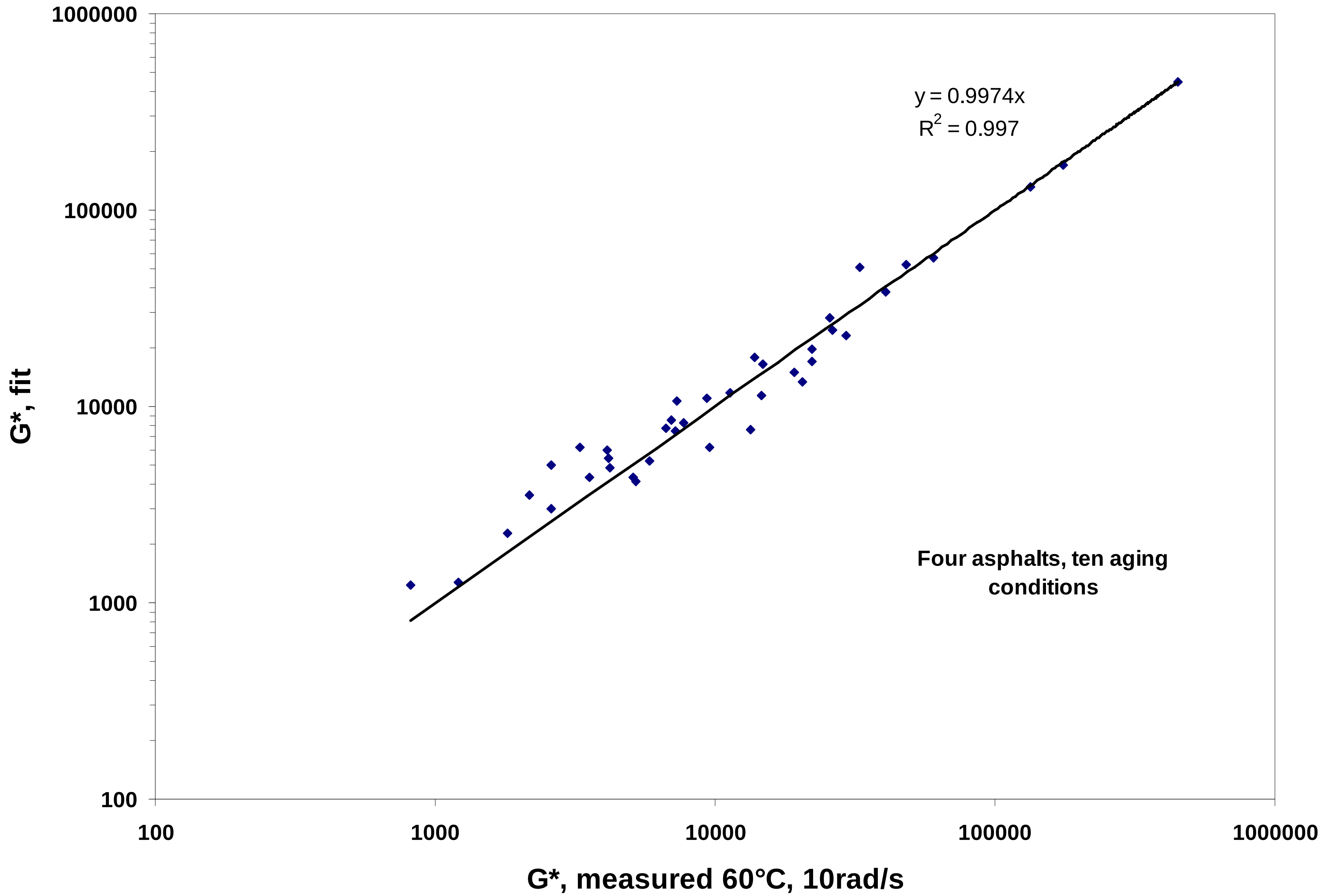
Comparison of Absorbances for Laboratory Sample AAM-1



*Relationship Between Absorbance at 1212 cm^{-1} and G**



G* Correlation Using Absorbance at 1212 cm^{-1}



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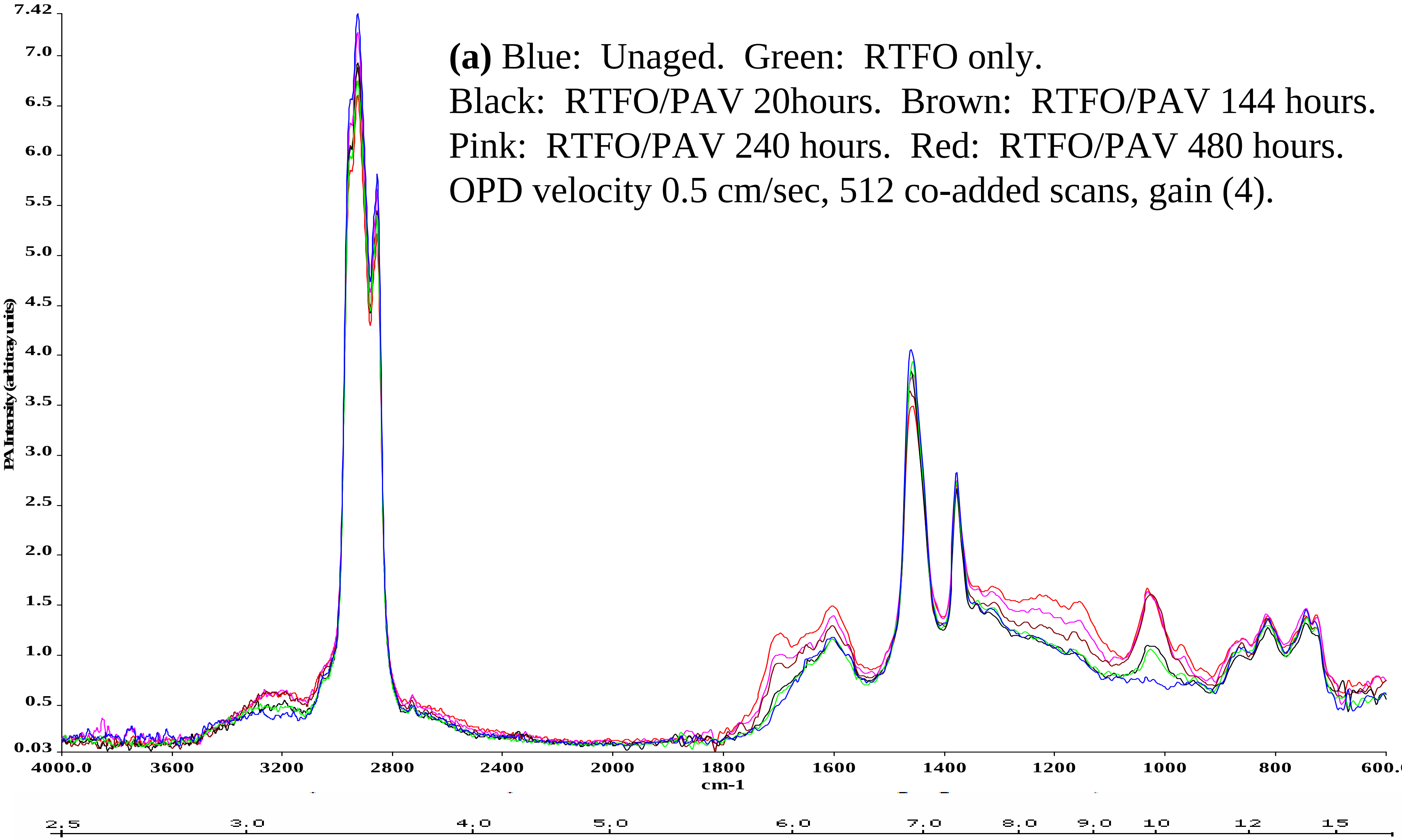
PA spectra changes on oxidation of AAD-1



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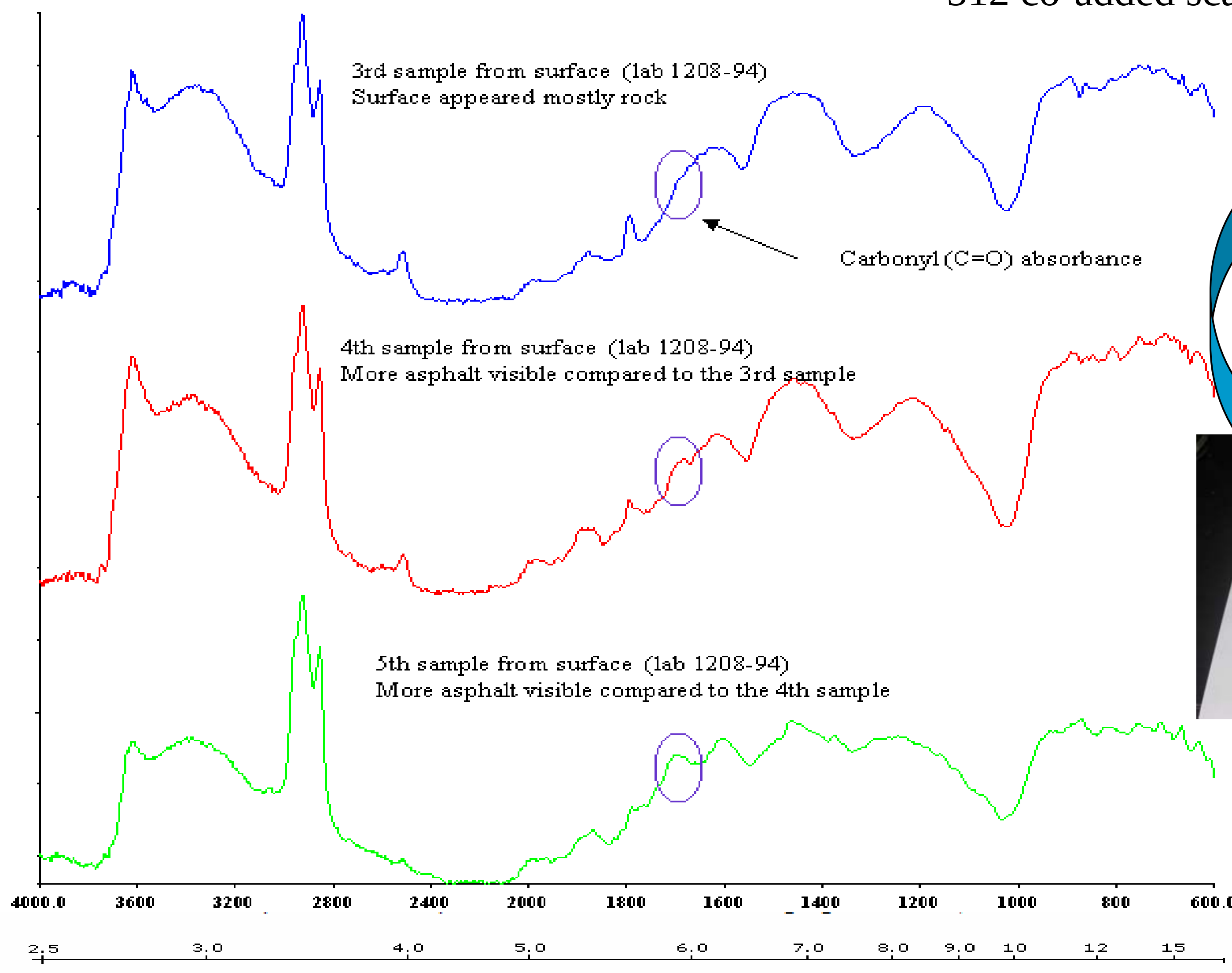
Photoacoustic spectra – Arizona surface samples from AZ1-3b

512 co-added scans



Small (approx. 4 mm wide) samples removed from the surface

AZ1-3b core

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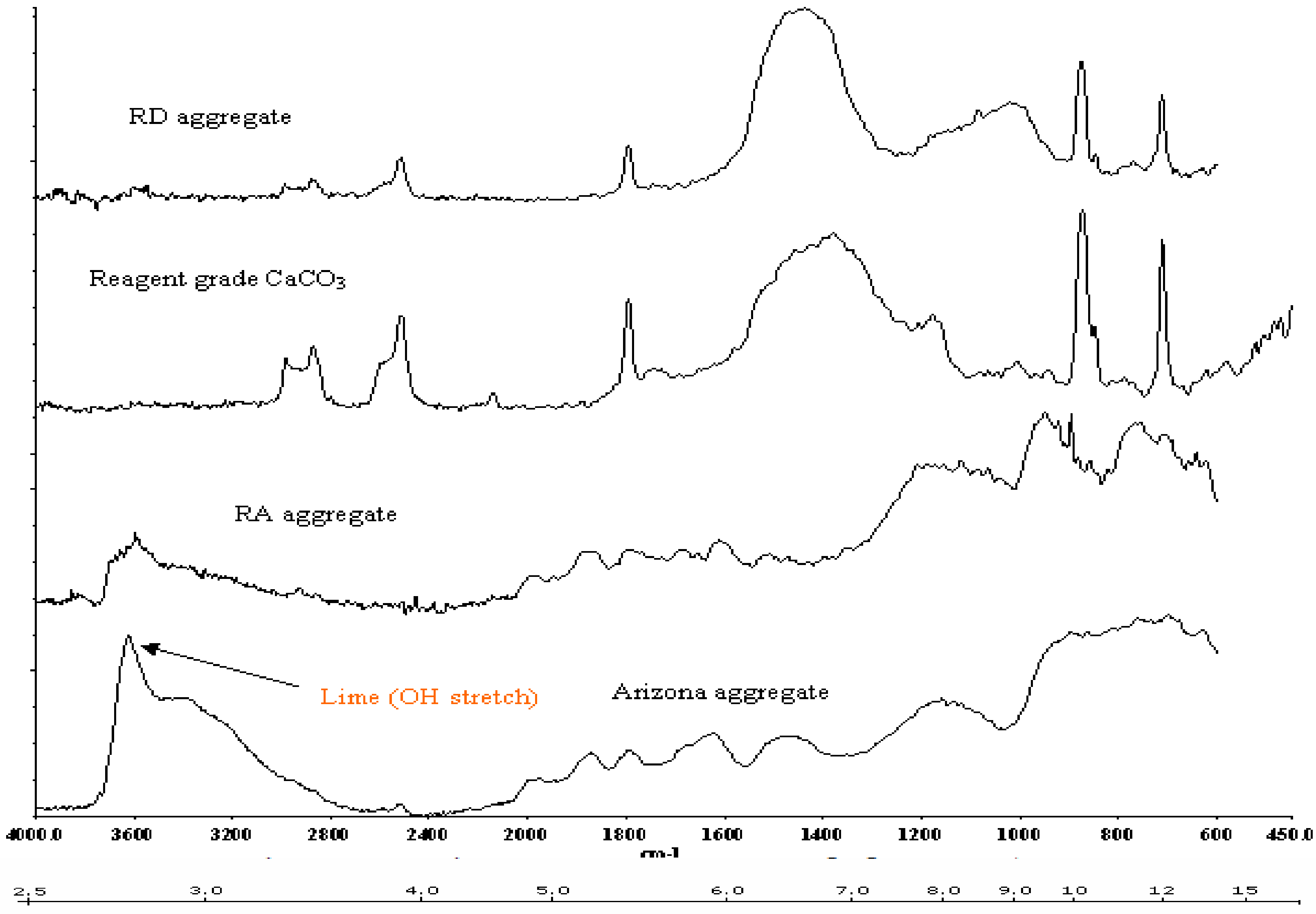
PA Spectra of Aggregates



What is Needed?

- **Validation sites for evaluating concepts and instrumentation**
  - **Multiple asphalt sources and grades**
  - **Multiple surface treatments**
  - **Save original materials**
- **Periodic distress surveys and coring**
- **High-resolution age profiling in cores**

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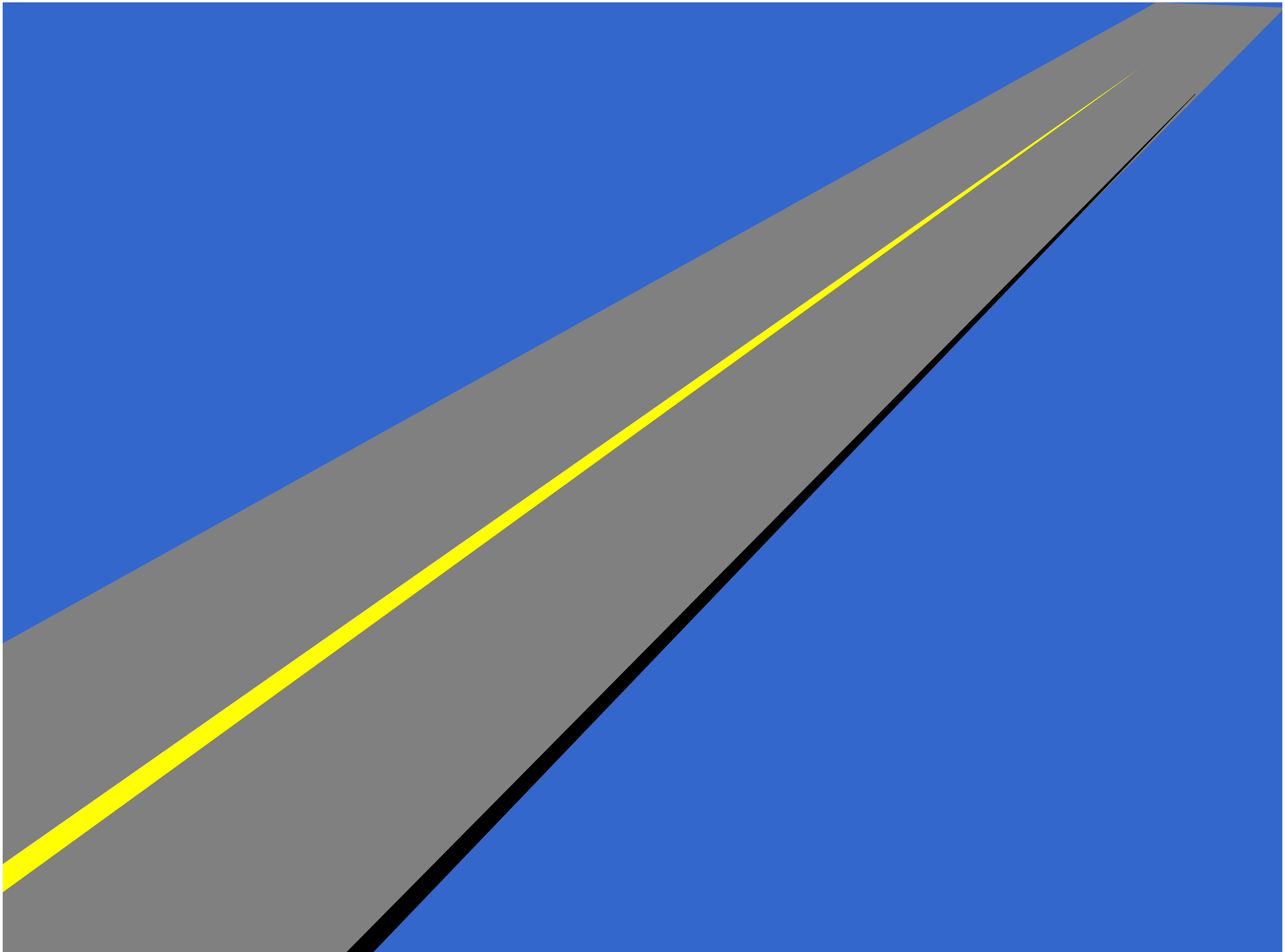
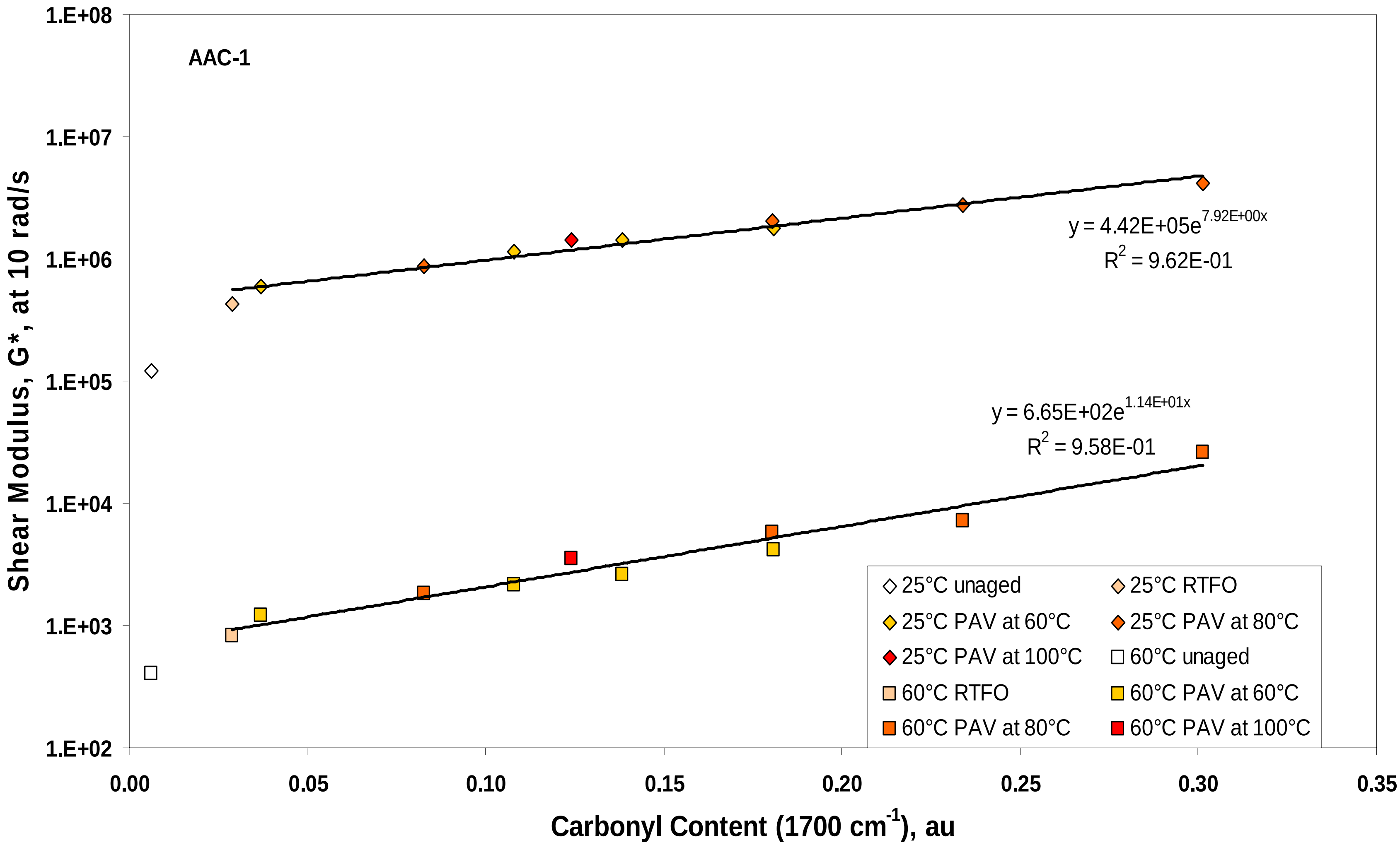
WRI Contribution

- **Age profiling in cores using micro extraction, photoacoustic techniques**
- **Field analyses with ASAP System**
- **Other specialized testing?**



G* Correlations With Carbonyl Content For AAC-1



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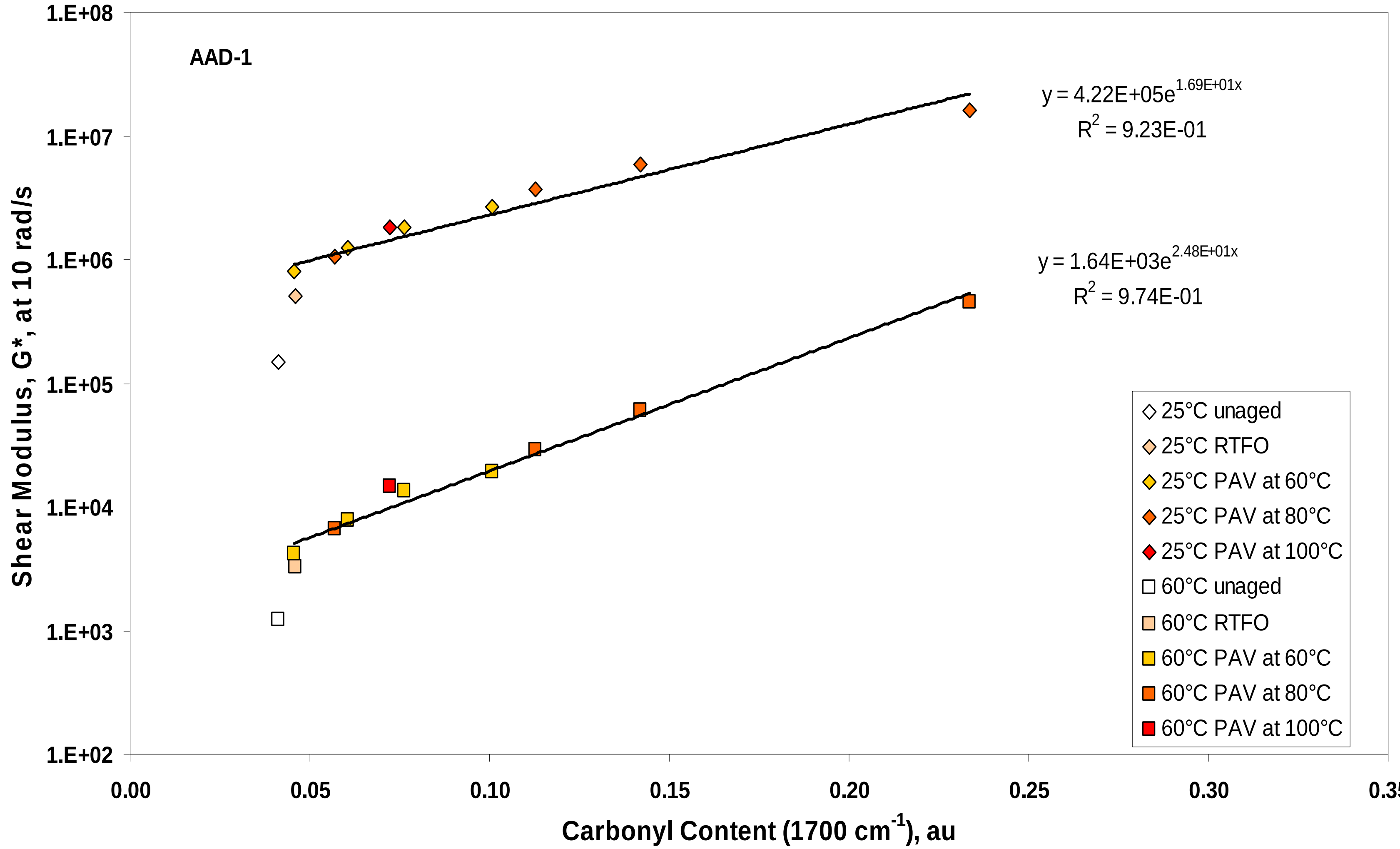
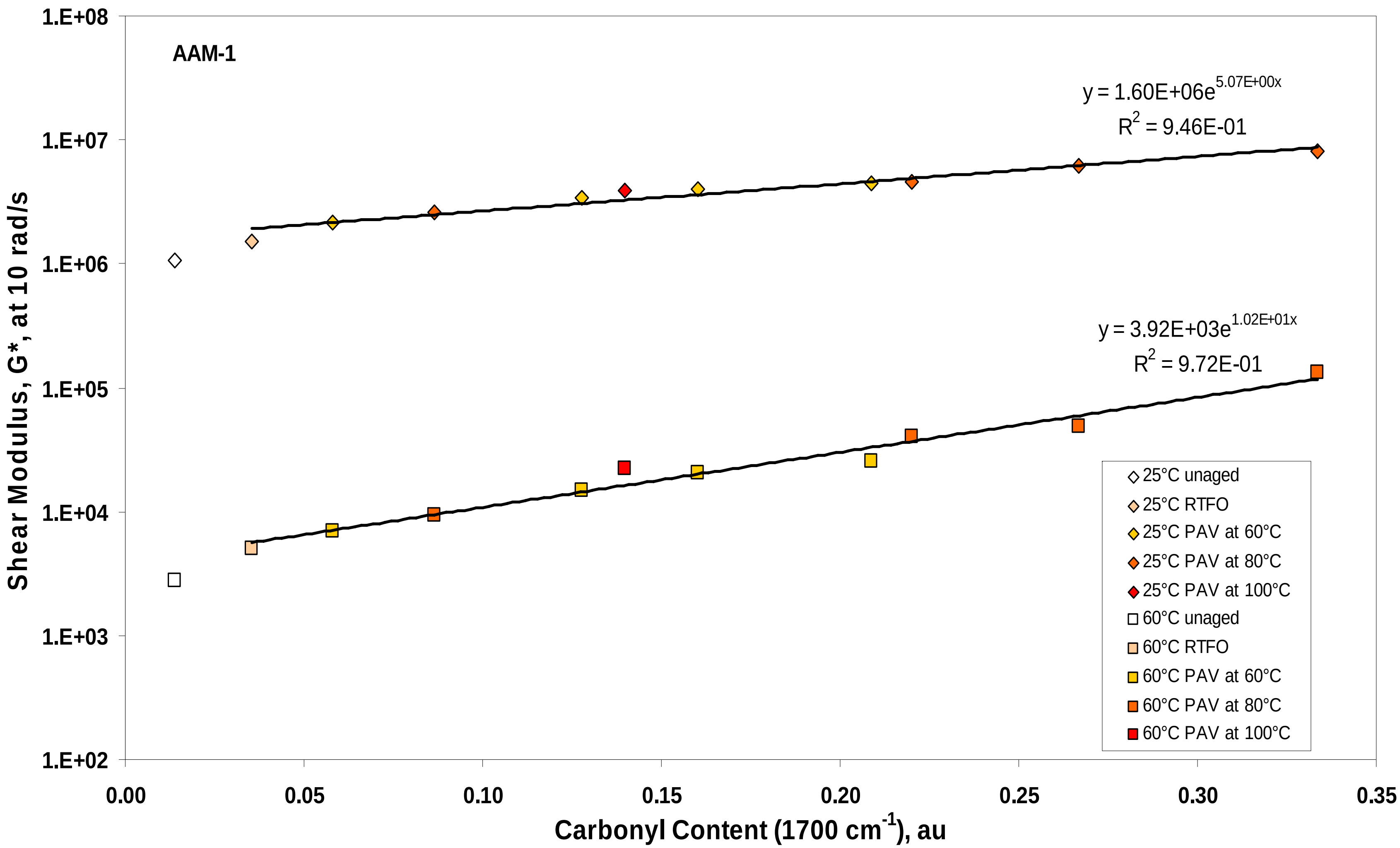
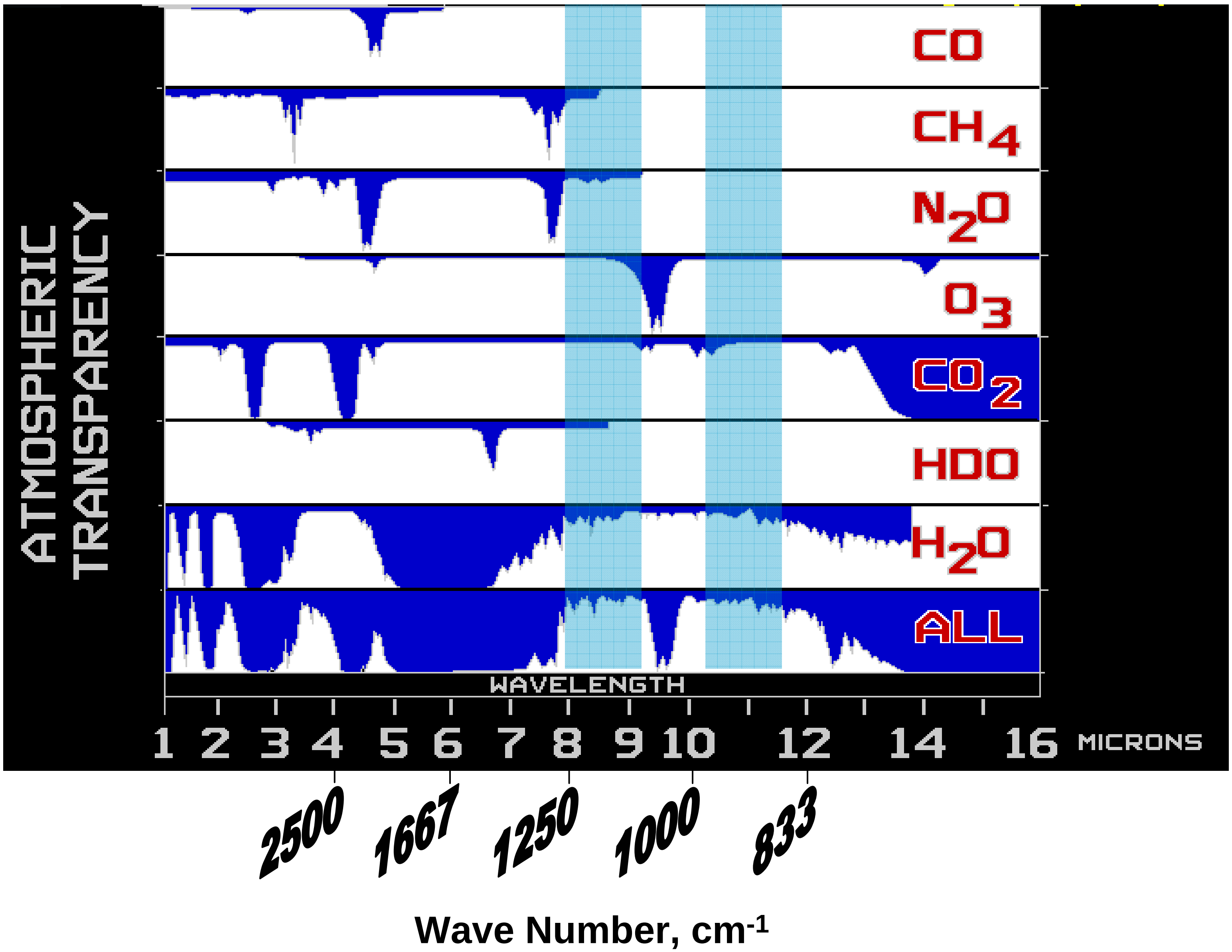
G Correlations With Carbonyl Content For AAD-1*



G* Correlations With Carbonyl Content For AAM-1




ATMOSPHERIC TRANSPARENCY
CO
CH4
N2O
O3
CO2
HDO
H2O
ALL
WAVELENGTH
1 2 3 4 5 6 7 8 9 10 12 14 16 MICRONS
2500
1667
1250
1000
833
Wave Number, cm-1