Studies of the Distribution of Hg in Coal Utilization Byproducts (CUB's) Generated by Appalachian and Midwestern Bituminous Coals

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CENTER FOR APPLIED ENERGY RESEARCH

Background

- **Previous Investigations**
  - **Hassett & Eylands (1997) and Miller et al. (1998)** noted relationship between Hg capture and gas temperature in laboratory experiments
  - **Gibb and Clarke** (2000) noted increase in Hg capture with increase in C and decrease in temperature in 1 MW experimental combustor

Background

- **Serre & Silcox** (2000, Ind. Eng. Chem. Res.) (Univ. Utah) did fixed-bed adsorption experiments using fly ash carbons
  - Final concentration correlates with amount of carbon
  - Several hundred ppm Hg adsorbed in >35% C ashes
  - Not nearly as effective when carbon is in flue gas stream

Background

- **Baltrus et al.** (2001; Energy Fuels) (NETL) studied fly ash carbons from multiple sources, including Dale ash and unnamed pond ash processed by Fast Float
  - Surface area studies did not agree with CAER studies
    - They determined anisotropic carbons to be less adsorptive than isotropic carbons, opposite our findings

Objectives of CAER Research

1. **Baseline for Hg in CUBs and Coal Feedstocks**
2. **Assess Parameters Controlling Hg in CUBs**
3. **Evaluate Control Technologies**
4. **Assess Impact on Utilization Potential of CUBs**

I. CAER Studies

- **CAER has conducted several studies of Hg capture by fly ash since 1993:**
  - A 500-MW unit burning Illinois Basin high-S coal
  - Shawnee: 150-MW unit burning Central Appalachian low-S coal
  - Dale: Density fractions of fly ash from Eastern Kentucky coal
  - Cooper: 100-MW unit burning coal from single mine

II. On-going CAER Studies

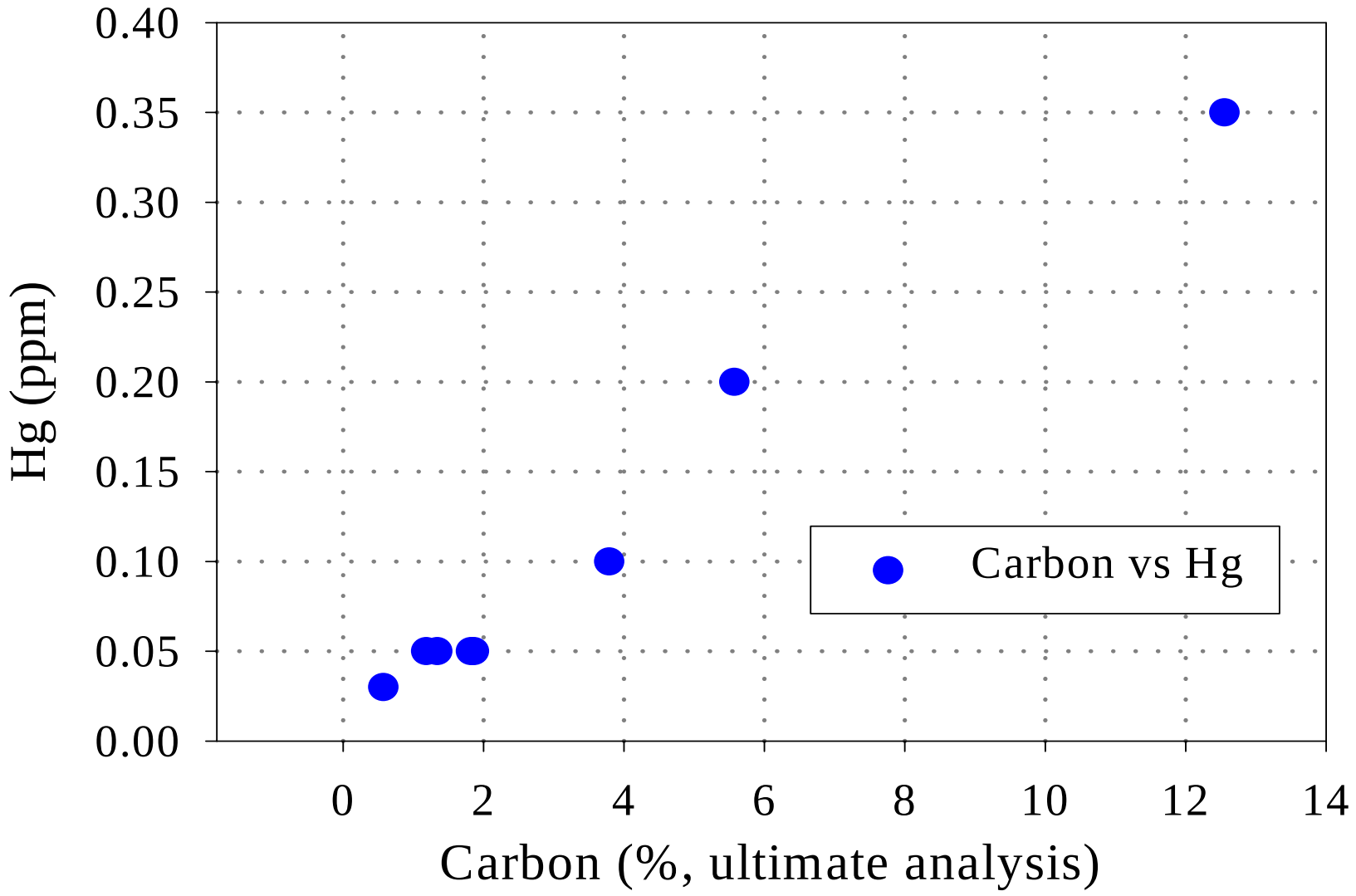
- **CAER Conducting Study of Hg Capture by Fly ash and FGD CUBs**
  - Based on extension of 1993 study of FGD systems at two LG&E plants
- **Pent-annual Survey of Kentucky Coal-fired Power Plants**
  - Collection and analysis of coal, fly ash, bottom ash, FGD, etc.

Focus on Utilities in Kentucky and Adjacent States

Ia. 500-MW Unit Burning Illinois Basin High-s Coal

- **Coal blend dominated by high-S, high volatile C bituminous Illinois Basin coal**
- **Coal and fly ash collected twice in consecutive months**
- **ESP fly ash sized at 100, 200, 325, and 500 mesh**
  - Insufficient +100 mesh ash for analysis
- **Hg part of large suite of elements analyzed**

Data for Unit No.1



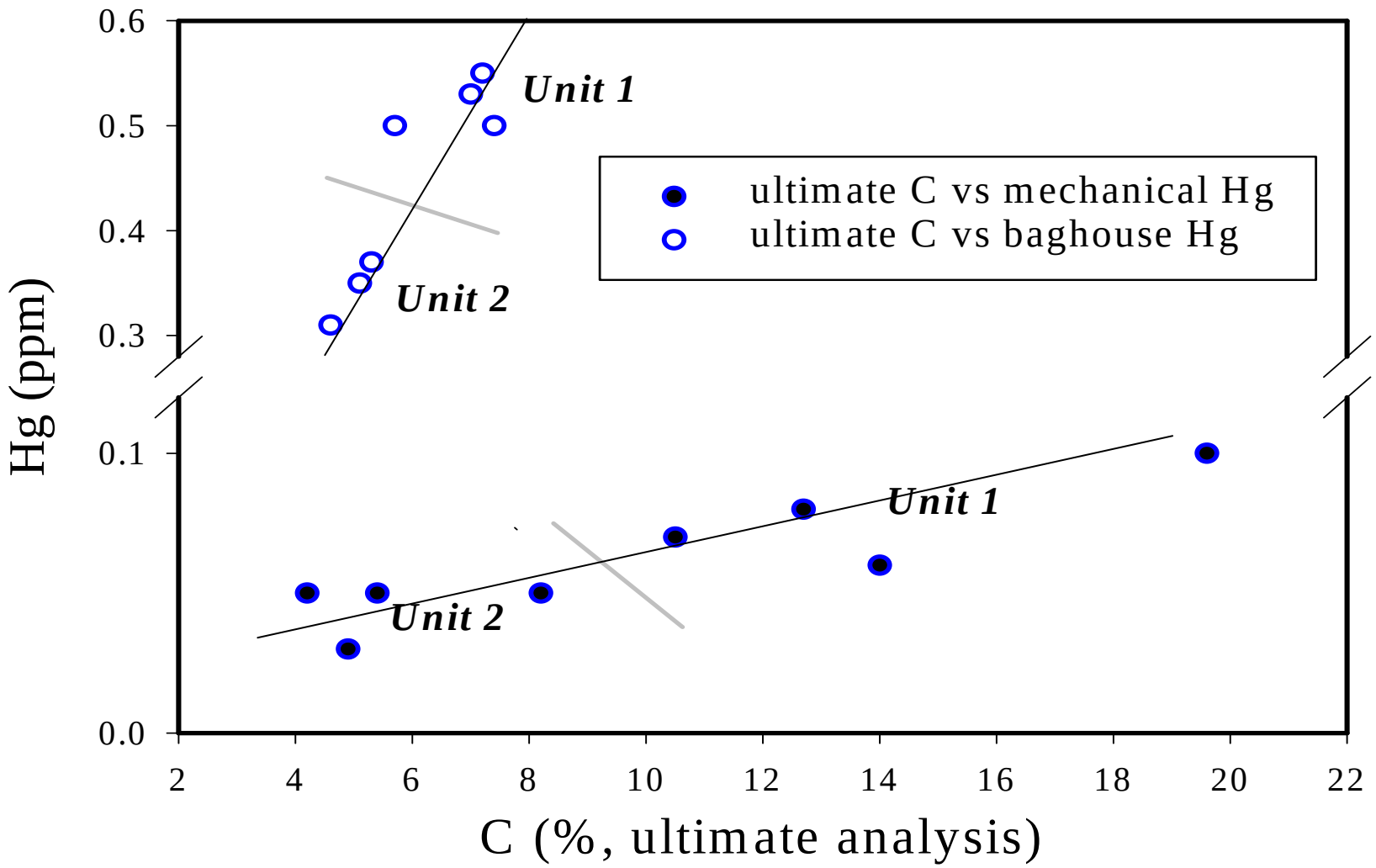
Ia. 500-MW Unit Burning Illinois Basin High-S Coal

- **Good relationship between Hg and percentage of fly ash carbon**
- **Constants:**
  - Flue gas temperature same for both collection times
  - Fly ash carbons similar in both cases

Ib. 150-MW Unit Burning Central Appalachian Low-s Coal

- **Collection of mechanical- and baghouse-separation fly ashes from identical 150 MW units burning Central Appalachian low-S coal**

Appalachian Coal: C vs Hg



Ib.150-MW Unit Burning Central Appalachian Low-s Coal

- **Gas temperature known**
  - 364 ^{o}C entering mechanical separation,
  - 172 ^{o}C at exit
  - – Baghouse temperatures not precisely known
- **Hg capture function of both fly ash C and flue gas T**
  - – Fly ash carbon petrography more complex than in previous example

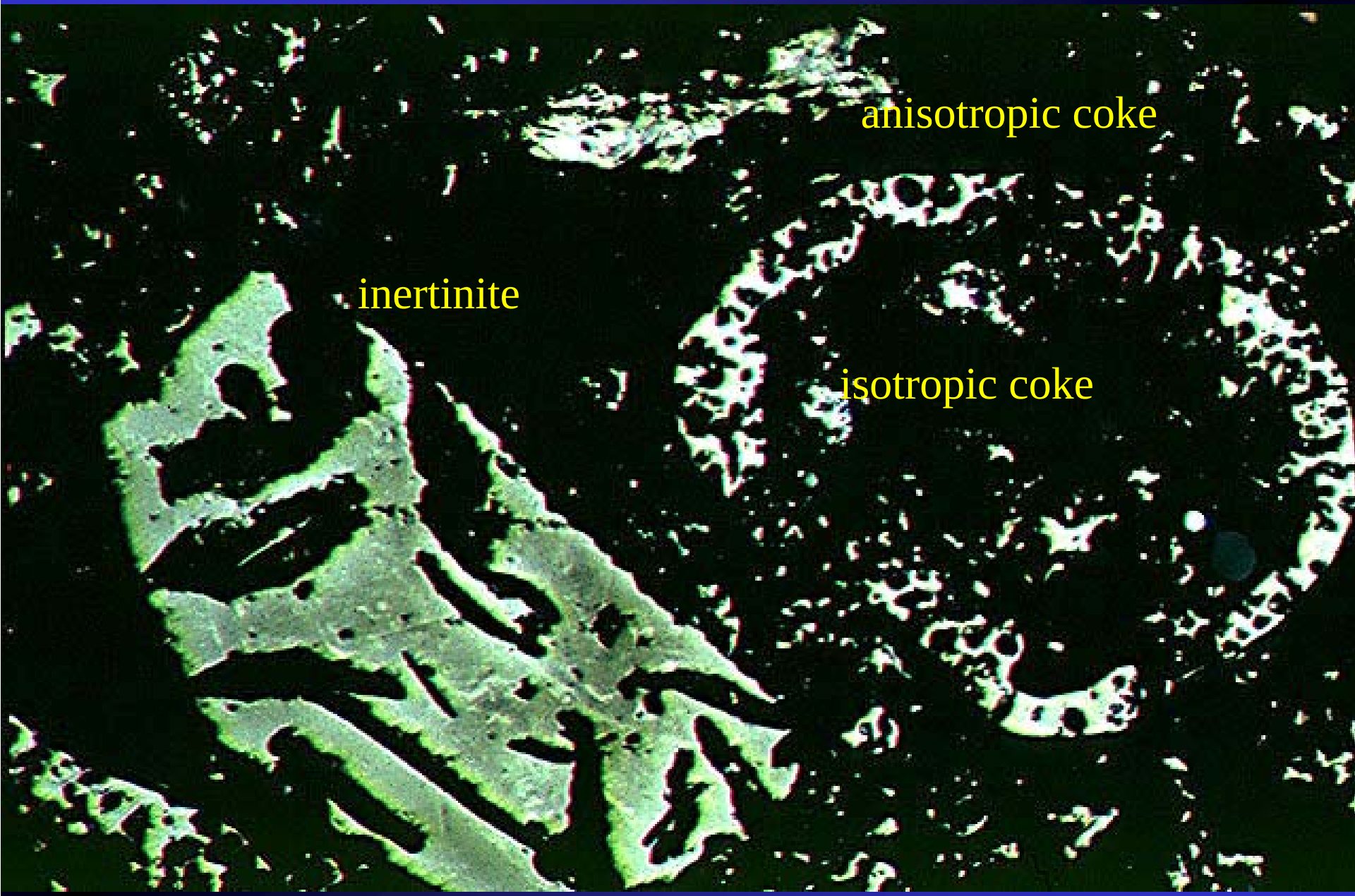
Ic. Density Fractions of Fly Ash*

- **Collected mechanical fly ash at 70 MW unit 3 at East Kentucky Power's Dale Station**
- **Screen ash at 140 mesh (106 microns)**
- **Concentrate C with triboelectrostatic separation**
- **Isolate C forms through density-gradient centrifugation (DGC)**
- **Petrographic, BET, and chemical analyses (including HG via LECO AMA 254) of DGC splits**

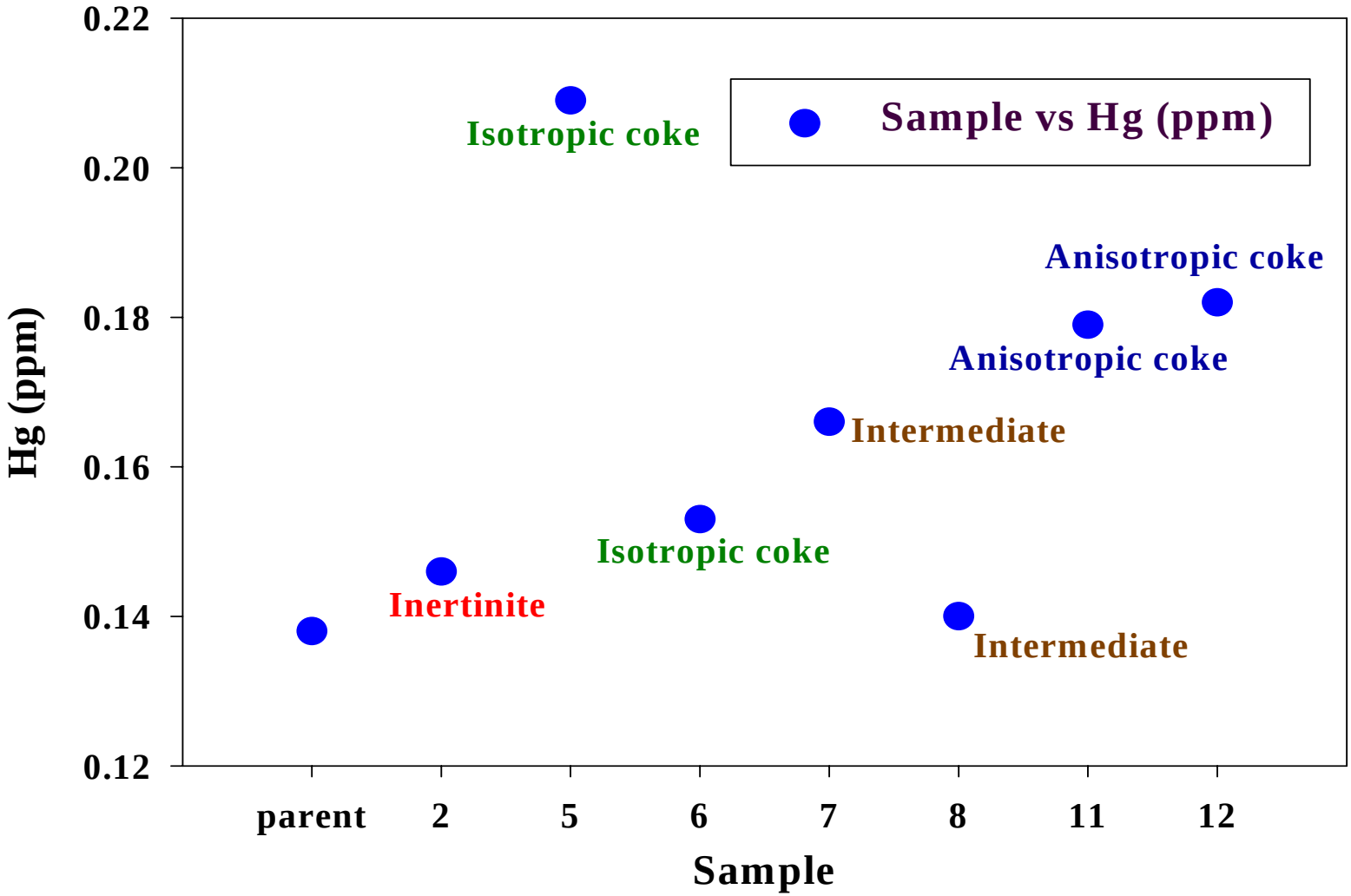
Work also with D. Taulbee and Merche Maroto-Valer

Ic. Fly Ash Petrography

- **Inorganic** ***neoformed***
  - glass
    - 70 to >90% of most FA
  - mullite
  - spinel
- **Inorganic** ***coal derived***
  - quartz
- **Organic** ***neoformed***
  - **isotropic coke**
  - **anisotropic coke**
- **Organic** ***coal (or fuel) derived***
  - **inertinite**
  - petroleum coke


anisotropic coke
inertinite
isotropic coke

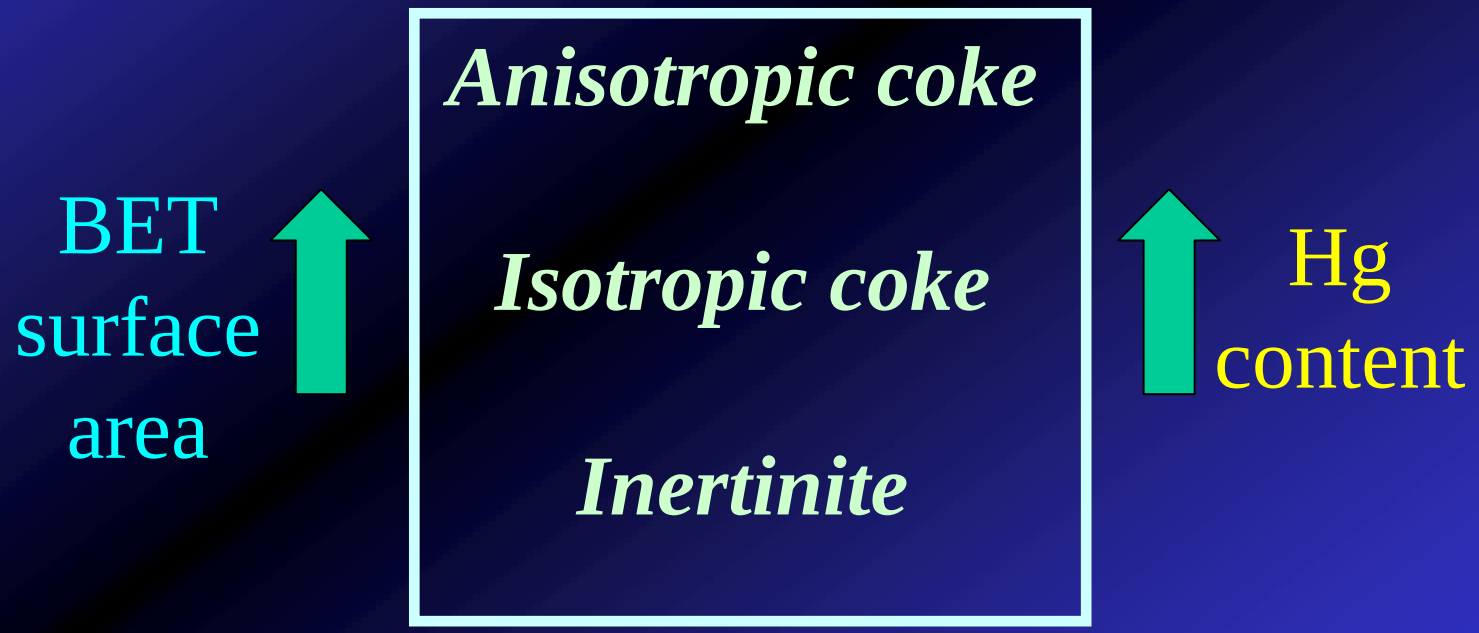
DCG Concentration vs. Hg Content



Ic. Dale Fly Ash Petrography

Sample	density (g/cm3)	Hg (ppm)	BET area (m2/g)	Inert	Iso coke	Aniso coke	Glass
parent	na	0.138	na	5.5	24.0	61.0	9.5
2	1.479	0.146	15	76.5	7.0	1.0	15.5
5	1.740	0.209	25	13.1	72.1	8.7	6.0
6	1.763	0.153	23	7.7	65.9	20.9	5.6
7	1.788	0.166	na	3.3	48.4	45.0	3.3
8	1.837	0.140	na	0.0	36.0	62.0	2.0
11	1.912	0.179	35	1.5	22.0	71.0	5.5
12	1.929	0.182	36	0.0	19.5	76.0	4.5

Ic. BET Surface Area vs. C forms
Hg content vs. C forms



Ic. Density Fractions of Fly Ash

- **Density, BET surface area & Hg content increase from inertinite to isotropic coke to anisotropic coke**
- **Caveats**
  - none of the fly ash concentrates are pure phases
  - some carbon forms can be partially or totally encased by other forms, not contributing to surface properties
  - gradations between the forms exist
  - sample collection not optimum for Hg capture

Id. Cooper: Single-source, High-Hg Coal

- **Utility identified, stockpiled, and, for two days, ran relatively high-Hg coal in 100 MW wall-fired unit**
- **Collected raw feed coal and pulverized feed coal**
- **Collected fly ash from all accessible hoppers**
- **Sampled coal, by lithotype, at source mine**

Id. Coal at the Mine

Upper 19 cm

- 5.75% total sulfur
- 3.36% pyritic sulfur
- 0.52 ppm Hg

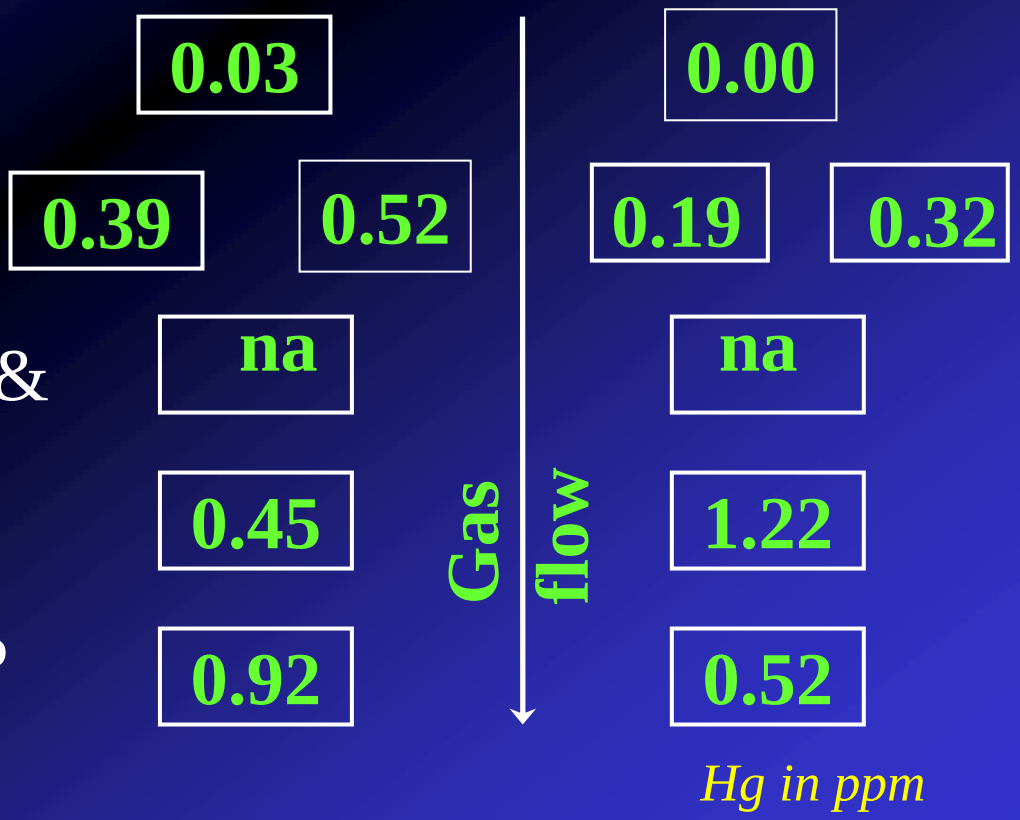
Lower 55 cm

- 0.60% total sulfur
- 0.02% pyritic sulfur
- <0.01 ppm Hg

Whole-seam Hg content is 0.22 ppm
Feed to Plant 0.24 ppm

Id. Cooper: High-hg, Single Mine Source Burn

- **Hg distribution is asymmetric**
  - –Mechanical hoppers 5 & 6 have higher Hg than hoppers 3 & 4
  - –Opposite trend for ESP hoppers



II. Ongoing Studies, Hg Distribution in Byproducts

- **More controlled study is anticipated with 2002 sampling of Kentucky power plants**
  - Part of survey of plants conducted every five years
  - 21 plants among 7 utilities
  - Survey of production & utilization/disposal of CUB's, changes in environmental controls, plus collection and analysis of coal and CUB's

IIa. FGD Studies – Ongoing

- **Investigated two power plants with three different FGD methods in 1993**
  - Emphasis on F distribution in original study
  - Re-investigating samples for Hg
  - Re-sampled one plant due to change to gypsum production from sulfite production

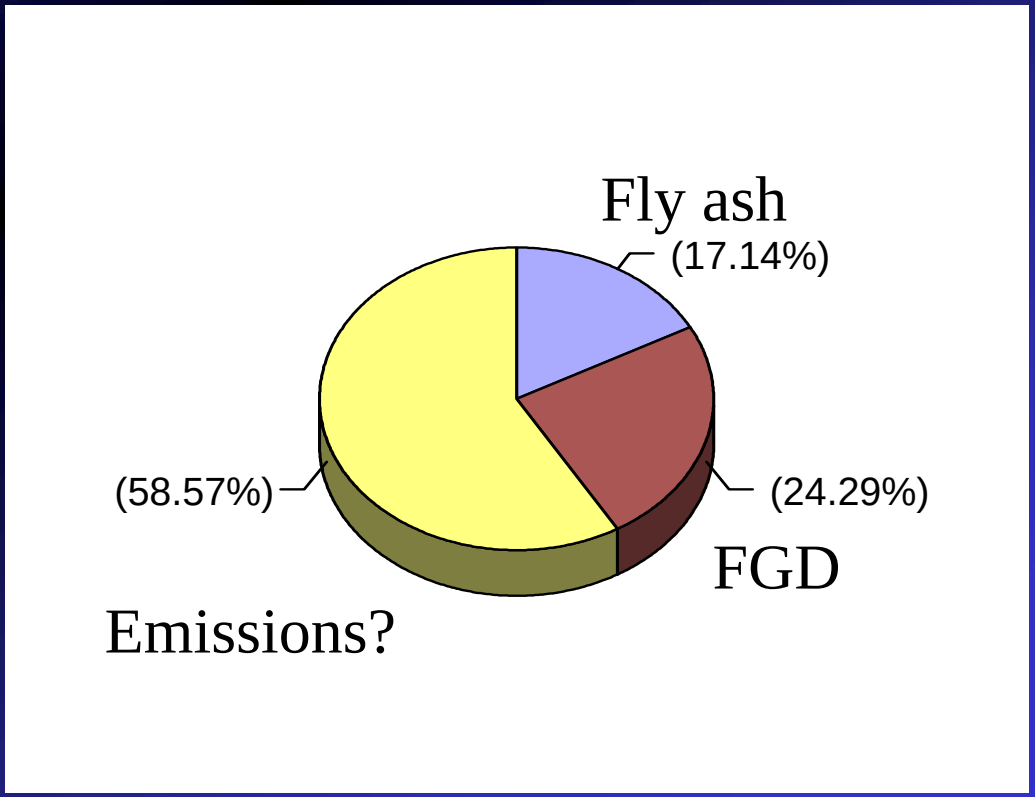
IIa. FGD Studies

	Jul 93	Aug 93	Oct 93	Nov 93	Jan 02
Coal	87	89	101	n.a.	74
FA	40	38	125	17	77
FGD	279 Sulfite	260 Sulfite	293 Sulfite	273 Sulfite	142 Gypsum

Hg in ppb

IIa. Hg Distribution In Byproducts

- **Preliminary estimate based on Jan 02 collection at one plant**
  - 0.28 t/a Hg in coal
  - 0.048 t/a Hg in fly ash
  - 0.068 t/a Hg in FGD
  - 0.164 t/a emissions?

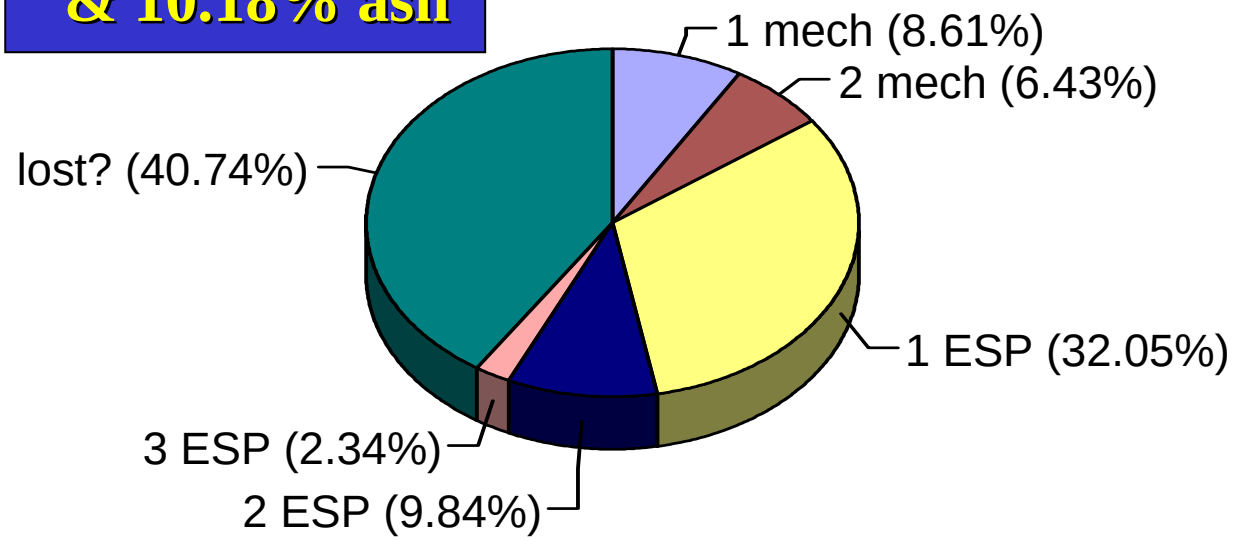


IIb. Hg Distribution – No FGD

Two rows of mechanical hoppers and three rows of ESP's

-based on assumption of 60:40 mechanical:ESP split and 80% fly ash capture by each row

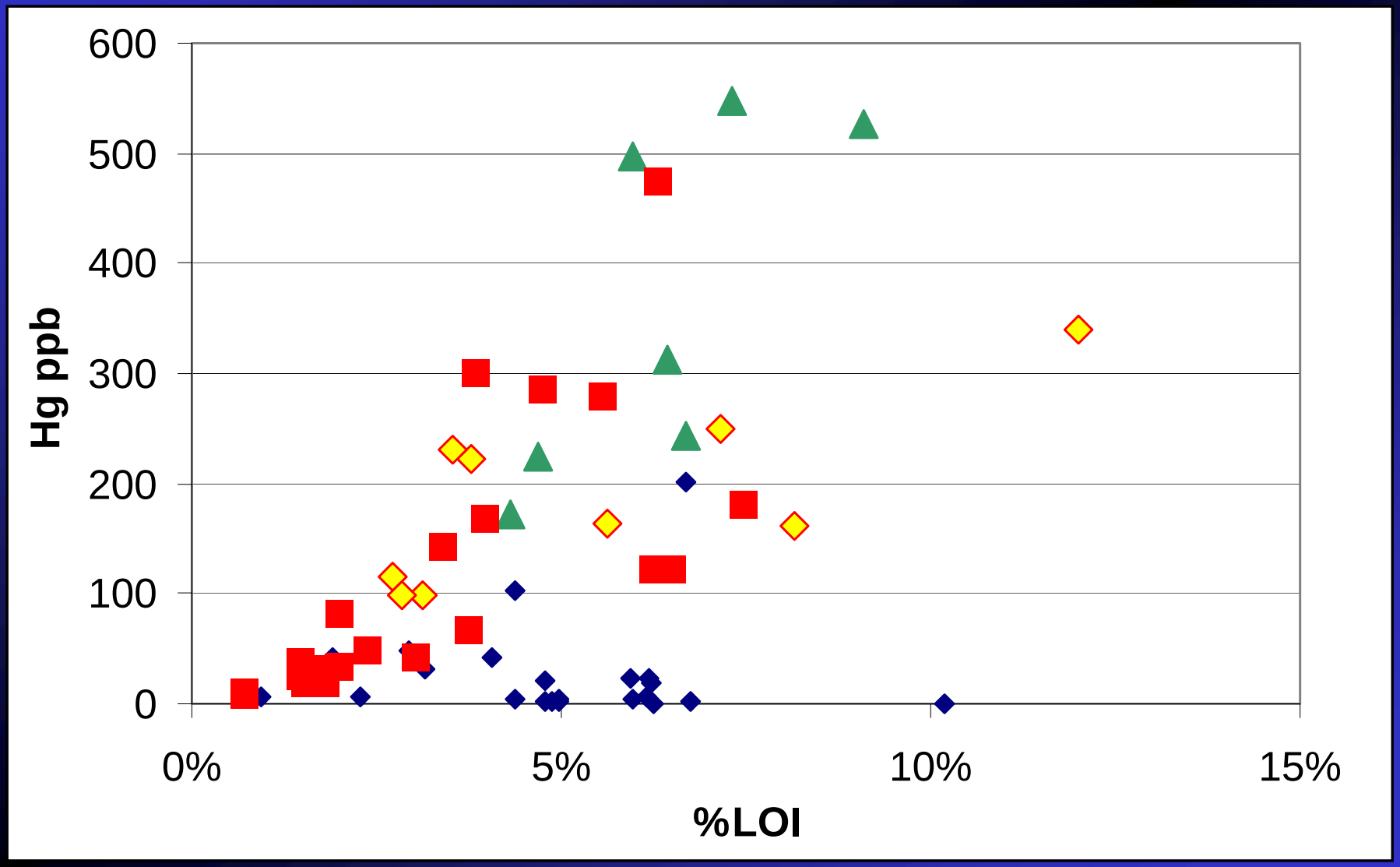
Feed coal –
0.111 ppm Hg
& 10.18% ash



Fly ash –
0.808 ppm Hg
(cumulative)

IIc. Hg vs LOI in Fly Ash

2002 Survey Ongoing



IIc. Hg in CUBs
2002 Survey Ongoing*

Hg in ppb	Hg ppb	High	Low	N
Coal	110	178	57	11
F. Ash	130	550	<1	80
B. Ash	9	14	1	8
FGD	n.s.	140	75	5
Mill T.	890	1,240	440	13

**40% complete*

III. Summary

- **Studies have demonstrated relationships among:**
  - **Amount of fly ash carbon and Hg capture**
    - More C = More Hg
  - **Decreasing flue gas T and Hg capture**
    - Lower T = More Hg
  - **Fly ash carbon type and Hg capture**
    - Increased Hg from inertinite to isotropic coke to anisotropic coke

III. Summary

- **General trends complicated by:**
  - -isolation of carbons from surface
  - -gradations among carbon types
  - -blinding of surfaces by inorganics
  - -furnace configurations

- **Ongoing Research into:**
  - -changes in Hg in CUBs
  - -focus on FGD materials
  - -Hg in ponded/landfilled CUBs

Thanks !

to the Folks at

LG&E
KU
TVA
EKPC
WKE
&
AEP