GLOBAL MET COAL FOR INDIAN STEEL INDUSTRY

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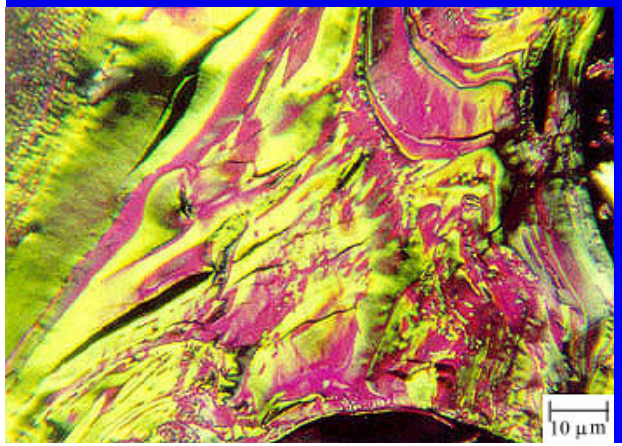

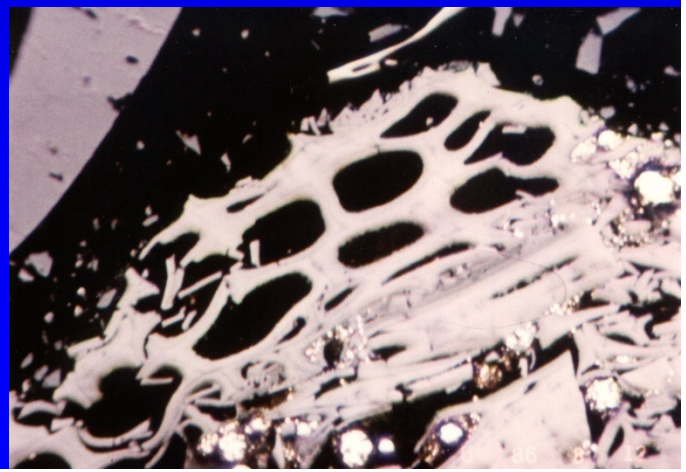

A MODERN DAY FABLE

During my university years at Boston

Lamenting my lost memory of

Parrots singing on a Mango Tree

My father sent me a tape with a message

“Dedicated to the Memory of Forgotten Ones!”

Did I ever find those Mango Trees and Parrots while marching along my professional path?

The answer my friend is emerging in the next slide!

BRAZILIAN BATTERY AMIDST FRUITS HANGING FROM MANGO TREES SHOWS RED HOT COKE

THE BRAZILIAN GARDEN OF EDEN SITE DEVELOPMENT ACHIEVED BY PLACING HEAVY EMPHASIS ON:

- CONSERVATION OF ENVIRONMENT
- EFFICIENT UTILIZATION OF RESOURCES AND TECHNOLOGIES
- THINK OUT OF BOX PHILOSOPHY

OBJECTIVE

- ROAD MAP TO MEET INDIA'S GROWING DEMAND FOR COKING COAL

OUTLINE

1) LEAPS & BOUNDS FOR STEEL - WHAT PATH THOU FOR COKING COAL

2) JAPAN SYNDROME MODEL FOR INDIA

3) NEW FRONTIERS - MAKING COKE FROM POOR QUALITY COALS

4) SUMMARY

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LEAPS & BOUNDS FOR STEEL – WHAT PATH THOU FOR COKE & COAL

- UNDER STRONG STEEL GROWTH SCENARIO
  - FROM 56 MT (2009) TO 177 MT (2020-21)
- UNDER STRONG COKE GROWTH SCENARIO
  - FROM 25 MT (2009) TO 81 MT (2020-21)
- UNDER STRONG MET COAL GROWTH SCENARIO
  - FROM 35 MT (2009) TO 113 MT (2020-21)

PATH TO STEEL TARGET WOULD BE DIFFICULT IF MET COAL SUPPLY NOT SECURED!

(Steel, Coke Data from Dr. A. Feroz, 2005)

WHERE ARE THE COKE PRODUCTIONS (M. Dietz, 1999)

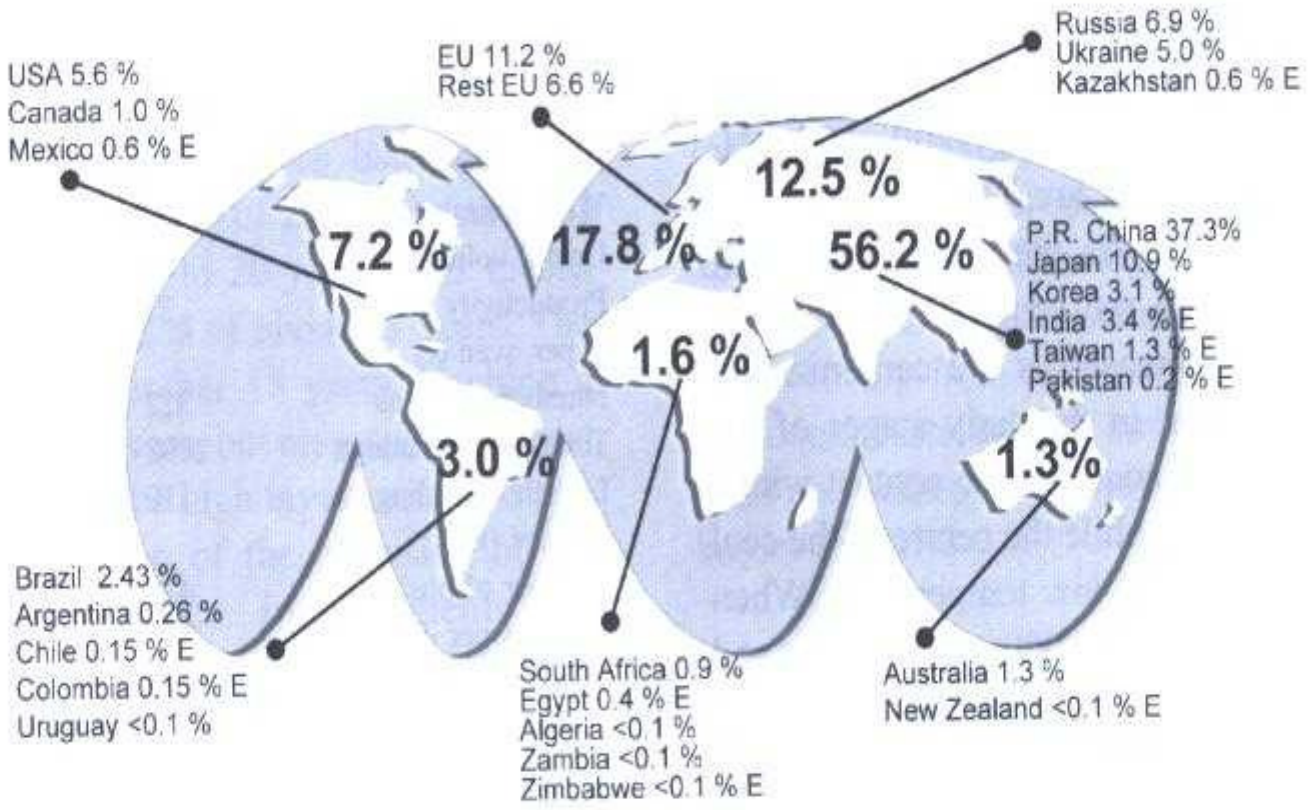

Fig. 8. Worldwide distribution of coke production on the basis of 324.4 Mt for 1999. E: estimated.

SCENARIO OF EMERGING COKE CENTERS

- WE PREDICT FUTURE SCENARIO OF EMERGENCE OF THREE (FOUR) WORLD COKE MAKING CENTERS
- ASIA – CHINA/INDIA
- RUSSIA, CIS-EASTERN EUROPEAN COUNTRIES
- SOUTH AMERICA
- AFRICA (A Distant Fourth)

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JAPAN SYNDROME MODEL FOR INDIA - RAW MATERIAL PAUCITY/DESIRE TO BUILD A NATION

THREE PRONGED STRATEGY :

1) SECURE SOURCES OF RAW MATERIALS (MET COAL) – For Domestic & Globally: Long term Coal Contracts; Secure Mines; Joint Ventures; Find ways to use widely abundant Low Rank Poor Coking Coals

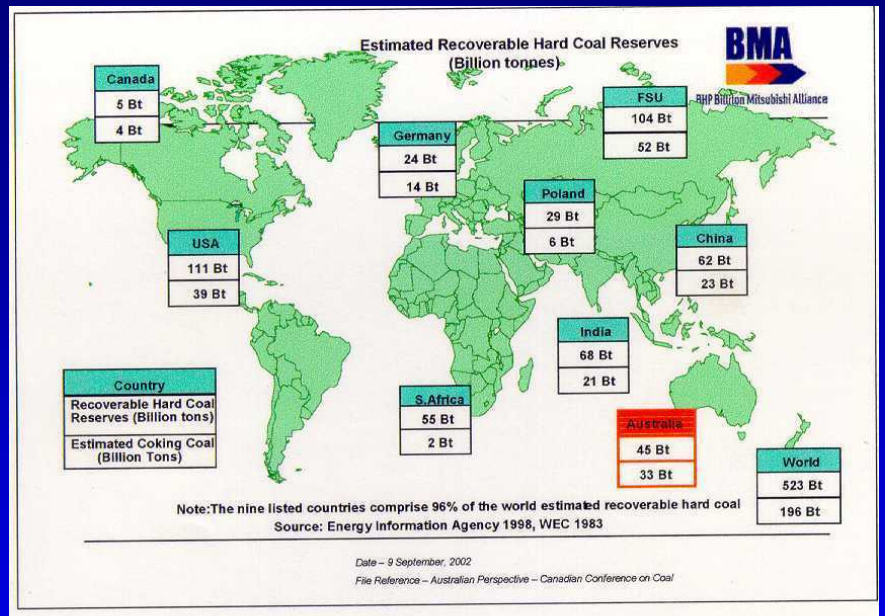
1) DEVELOP COKE SELF SUFFICIENCY – Development of Captive and Contract Coke Plants – Domestic and Globally

3) EXPORT EXCESS COKE

SECURE SOURCES OF RAW MATERIALS (MET COAL)

- ROAD MAP TO MEET INDIA'S GROWING DEMAND FOR COKING COAL

WORLD COAL RESERVE (BMA, 2004)



There are 9 major sources of coal which comprise approximately 96% of the worldwide recoverable reserves. They are: -

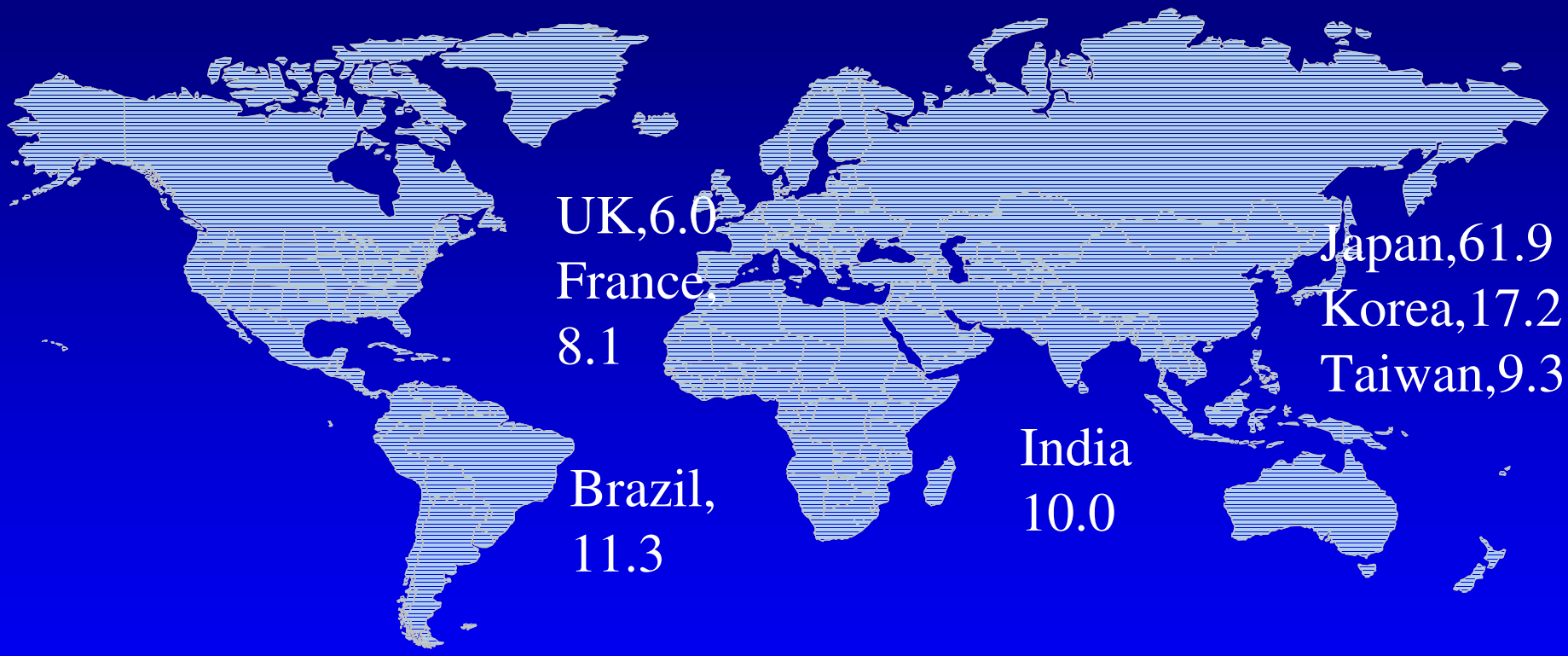
Canada – 4 Bt
USA – 39 Bt
S Africa – 2 Bt
Germany – 14 Bt
Poland – 6 Bt
India – 21 Bt
Russia – 52 Bt
China – 23 Bt
Australia – 33 Bt

MAJOR MET COAL EXPORTER MT, 1999

Others = 15.6; Total = 187.6 (Source: IEA, 1998, 2000)

Note: Now China net importer, about 30 MT, 2010)

IMPORTER, MT, 1999



Others=61.8; Total=183.6 (Source=IEA, 1998,2000)

Note: China Net Import=30 MT (2010); India=25 MT(2009)

Table showing metallurgical coal import outlook (EIA. DOE)

	2002	2010	2025
Europe	53.0	58.3	54.8
Americas	20.5	27.7	31.3
Asia	124.7	134.3	143.7
Total	198.2	220.3	229.8

WHO WOULD SUPPLY SUCH HIGH TONNAGES?

WORLD MET COAL PROSPECTS

WORLD COALQUALITY- some are very general, some represent one data point only

	HIGH	VOL	MEDIUM	VOL	LOW	VOL
	REFL	CSR	REFL	CSR	REFL	CSR
USA	0.95/1.10	65/75	1.27	64	1.63/1.4	40/6
CANADA	0.87	62	1.31	76	1.37	70
COLUM	0.99	61	1.29	74	1.44	62
AUSTR	0.95	60	1.17	68	1.57	74
CHIN/MA	1.02	75	1.33	70	1.45	72
RUSSIA	range	40-75	1.20	54	1.43	40
POLAND	0.99	46	1.20	40-60	1.4	ND

WORLD MET COAL MINES/RESERVES FOR ACQUISITION

RANKING OF PROSPECTS:

1) Criteria: Quality (Q), Reserve (R), Availability (A), Logistics (L)
2) If Availability & Logistics are not problematic, then prospect is ranked as Very Good.

WORLD MET COAL MINES/RESERVES FOR ACQUISITION

Mine	Quality	Reserve	Availability	Logistic	Prospec
USA	Good	V.Large	Difficult/Ea	Easy	V. Gooc
Russia	Good	V.Large	Difficult	Difficult	Good
Australia	Good	V.Large	Easy	Moderate	V. Gooc
Chin/Ma	Good	V.Large	Difficult	Difficult	Good
Canada	Good	Small	Easy	Easy	V. Gooc
Africa	Variable	Large	Difficult	Difficult	Good
Col/Inds	Good/Va	Small	Difficult	Difficult	Good

WORLD MET COAL SUPPLY/EXPANSION REVIEW (Courtesy: J.Truman, Wood Mackenzie, Intertech 2010)

1) CHINA: 170 MT Expansion between 2010-2025
2) MANGOLIA: 7.5 MT from current to 25 MT by 2014
3) INDONESIA: BHP Billiton/Adaro, Maruwai; Trial short term; full production by 2016
4) AUSTRALIA: Numerous expansion at BHP; Xstrata; Rio Tinto; Peabody (?)
4) Russia: Mechel (Elga) 1 MT 2011; Arcelor Mittal (?)
5) Mozambique: Riversdale/Tata (Benga), 2011 (Phase I=1.7 Mt); Vale (Moatize), 2011 (Phase I=13.5 MT)
6) Canada: Numerous expansion at Teck; Western Coal; Grande Cache
7) USA: Six steel companies bought 10 MTPA capacity; Potential for expansion=26.3 MT

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FIND WAYS TO USE WIDELY ABUNDANT LOW RANK POOR COKING COALS

- A MATTER OF SIMPLY PROPER COAL BLEND DESIGN
- LOOKING IN TO NEW TECHNOLOGIES – SHORT TERM
- LOOKING IN TO NEW TECHNOLOGIES – LONG TERM

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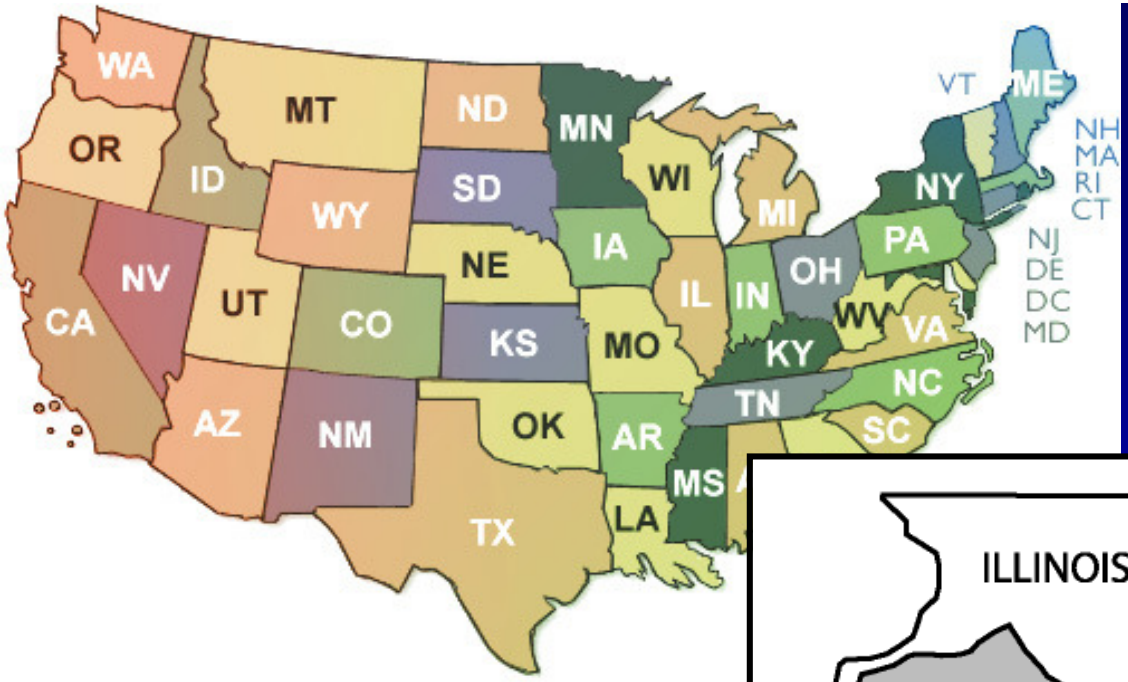
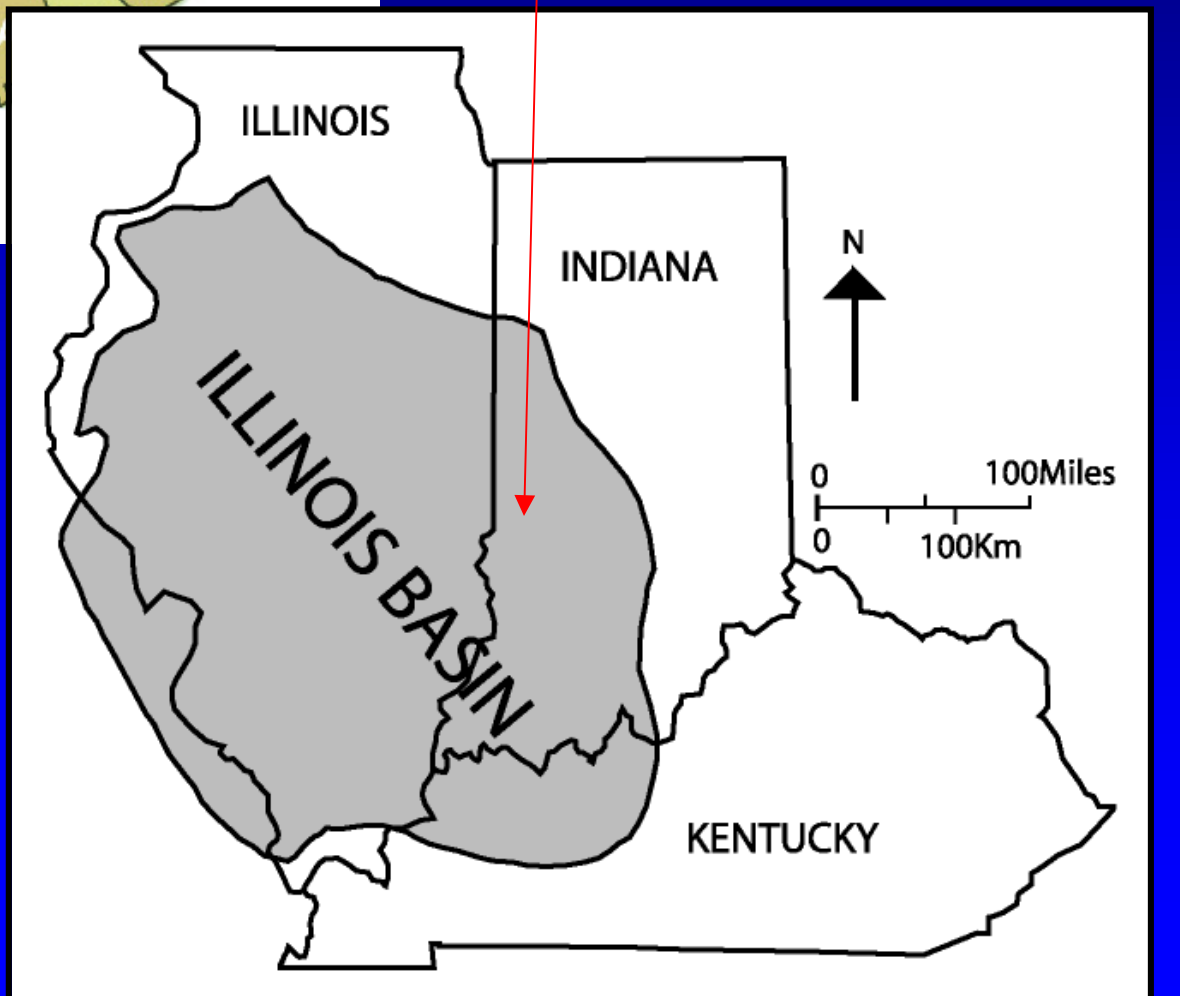


Area (grey) where the coal is present



Data on Brazil Formation coals from selected mines in Indiana.

Properties:	ILL	1	2	3	4	5	6	7	8
Reflectance	0.65	0.56	0.60	0.51	0.60	0.58	0.56	0.51	0.58
Max. Fluidity	3	12	18	4449	18	72	60	552	48
Fluid Range	41	76	57	91	67	77	73	71	64
Pred. CSR	27	56	54	50	42	48	43	40	50

(Note: Illinois Coal included for Comparison)

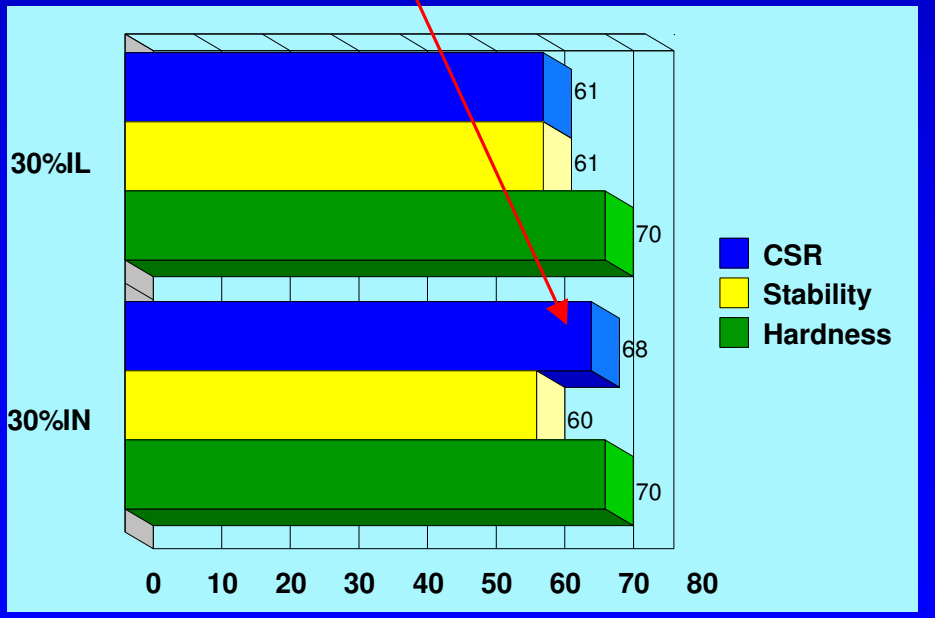
Most coals have relatively high CSR. All these coals are also low in sulfur (0.6-0.7% unwashed)

Carbonization Tests on Blends

	30IL-30EHV-40EMV	30IND-30EHV-40EMV
CSR	61	68
Stability	61	60
Hardness	70	
Wall Pr,kPa	70	
SHO Contr.	5.65	
	6.27	
	-7.99	-9.57

Note:SHO @52Bulk Density;2%Moisture

With the same proportions of other coals, 30% of Indiana coal results in significantly higher CSR than using 30% of Illinois coal (68 versus 61)



Commercial & Pilot Scale Tests

	I C	II C	III P	IV P
	16% Ind	25% Ind	45% Ind	50% Ind
	44% EHV	35% EHV	15% EHV	50% LVM
	40% EMV	40% EMV	40% WMV	Alabama
CSR	65	66	65	66
Stability	61	60	63	62
Coke sulfur (%, dry)	0.77	0.75	nd	nd
Coke ash (%, dry)	8.84	7.9	nd	nd
SHO contraction	nd	-5.3	-10.1	nd

Using Indiana coal in blends in proportions from 16 to 45% results in high CSR, good stability, and contraction

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NEW FRONTIERS TO CONQUER – CONTINUOUS COKE MAKING THAT TURNS OFF/ON BUT UTILIZES HIGH AMOUNTS OF LOW RANK POOR COKING COALS

- DR. RICHARD WOLFE – A U.S. BASED NUCLEAR PHYSICIST'S INNOVATION OF EARLY 90's
- MILD GASIFICATION THAT ENHANCES CARBON FORM WHILE COAL IS PRESSEED UNDER MOLTEN STATE GIVING RISE TO CHAR AND COAL OIL LIQUIDS
- RESULTANT CHAR FROM LOW RANK POOR COKING COAL HAS IMPROVED CSR WHICH ON BRQUETTING WITH PRIME COKING COAL/BINDER AND CALCINATION GIVES A STRONG MET COKE

Photograph of Char and Coal Oil Liquids from Form Coke Making

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CHANGING ALIGNMENT OF NEMATIC LIQUID CRYSTALS IN COKE MAKING VIA INDUCTION HEATING

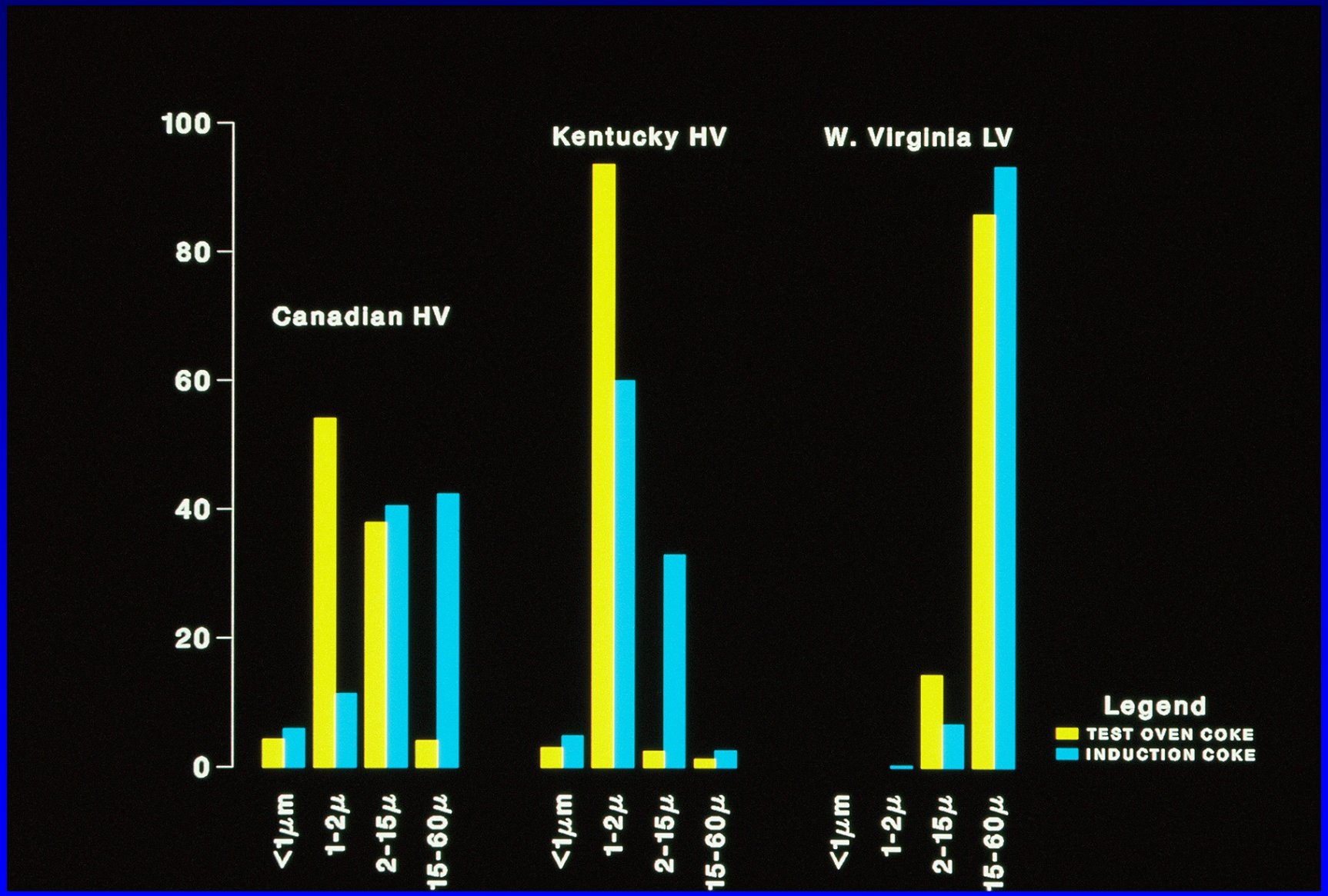
Objective

To identify effects of induction heating of coal on

- Coke carbon form
- Coke strength

COAL PROPERTIES

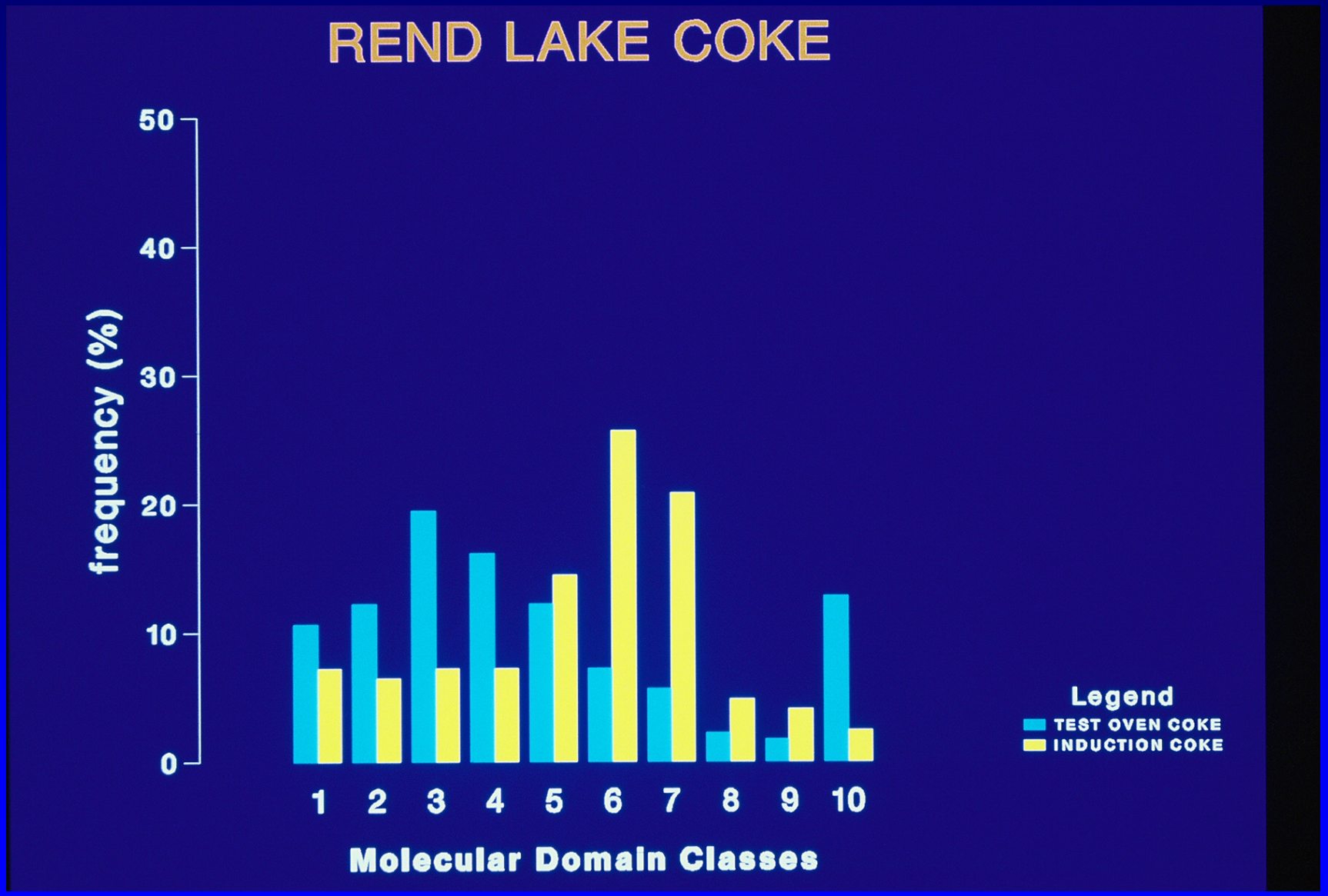
PROPERTIES	ILLINOIS	CANADIAN	KENTUCKY	W. VIRGINIA
Reflectance	0.69	0.87	0.99	1.5
VM(%db)	35.9	32.4	31.6	21.1
M.Fluidity	10	555	30000	730

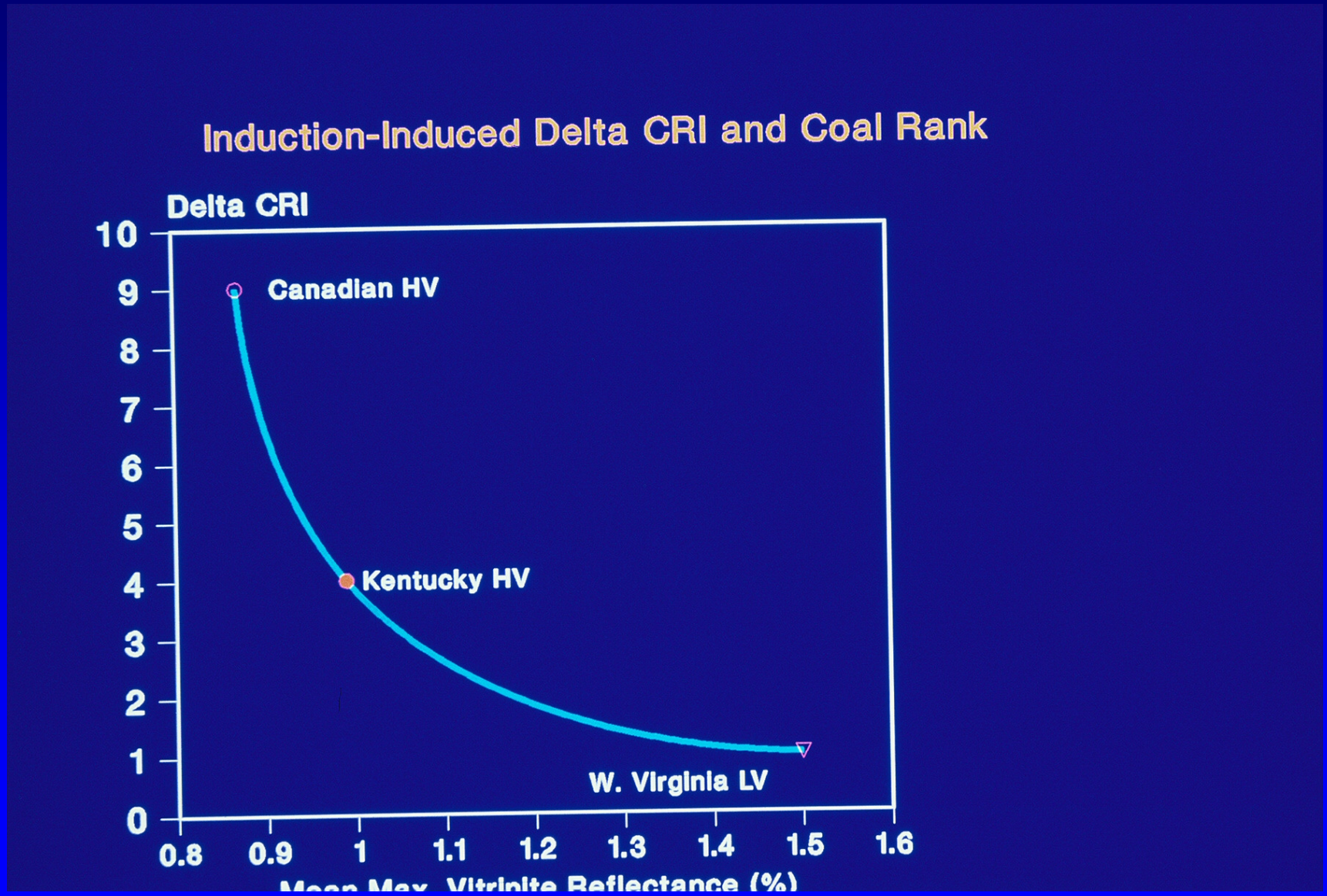

100
80
60
40
20
0
Canadian HV
Kentucky HV
W. Virginia LV
<1μm
1-2μ
2-15μ
15-60μ
Legend
TEST OVEN COKE
INDUCTION COKE

TEM COKE MICROTEXTURE

MOLECULAR DOMAIN	INDUCTION COKE ILLINOIS	OVEN COKE ILLINOIS
1	7.2	10.6
2	6.4	12.2
3	7.2	19.4
4	7.2	16.1
5	14.4	12.2
6	25.6	7.2
7	20.8	5.6
8	4.8	2.2
9	4.0	1.7
10	2.4	12.8

Shift D. Size:3-4 (PWT=10-25) to 5-7(PWT=25-100nm)


REND LAKE COKE
50
40
30
20
10
0
frequency (%)
1
2
3
4
5
6
7
8
9
10
Molecular Domain Classes
Legend
TEST OVEN COKE
INDUCTION COKE


Induction-Induced Delta CRI and Coal Rank
Delta CRI
10
9
8
7
6
5
4
3
2
1
0
Canadian HV
Kentucky HV
W. Virginia LV
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6

COKE PROPERTIES

	INDUCTION COKE CANADIAN	RADIANT COKE CANADIAN
CARBON FORM (%)		
LIGULAR	34.9	29.6
ACICULAR	42.9	45.8
GRANULAR	16.3	19.3
ISOTROPIC	5.9	5.3
COKE PROPERTIES		
COKE POROSITY(%)	61.0	64.0
REACTION STRENGTH (%)	25.0	7.0
REACTIVITY (%)	33.0	45.0

Conclusions

Induction heating results in

- Enhanced carbon form
- Enhanced coke strength properties
- Fast heating rate enhances carbon form and coke strength properties

Results indicate Potential for use in a Continuous Coke Making Process with Blends Rich in Low Rank Coals

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SUMMARY SOULTIONS TO NAVIGATE THROUGH INDIA'S COKING COAL TOWARDS SELF SUFFICIENCY

SUMMARY SOULTIONS TO NAVIGATE THROUGH INDIA'S COKING COAL TOWARDS SELF SUFFICIENCY

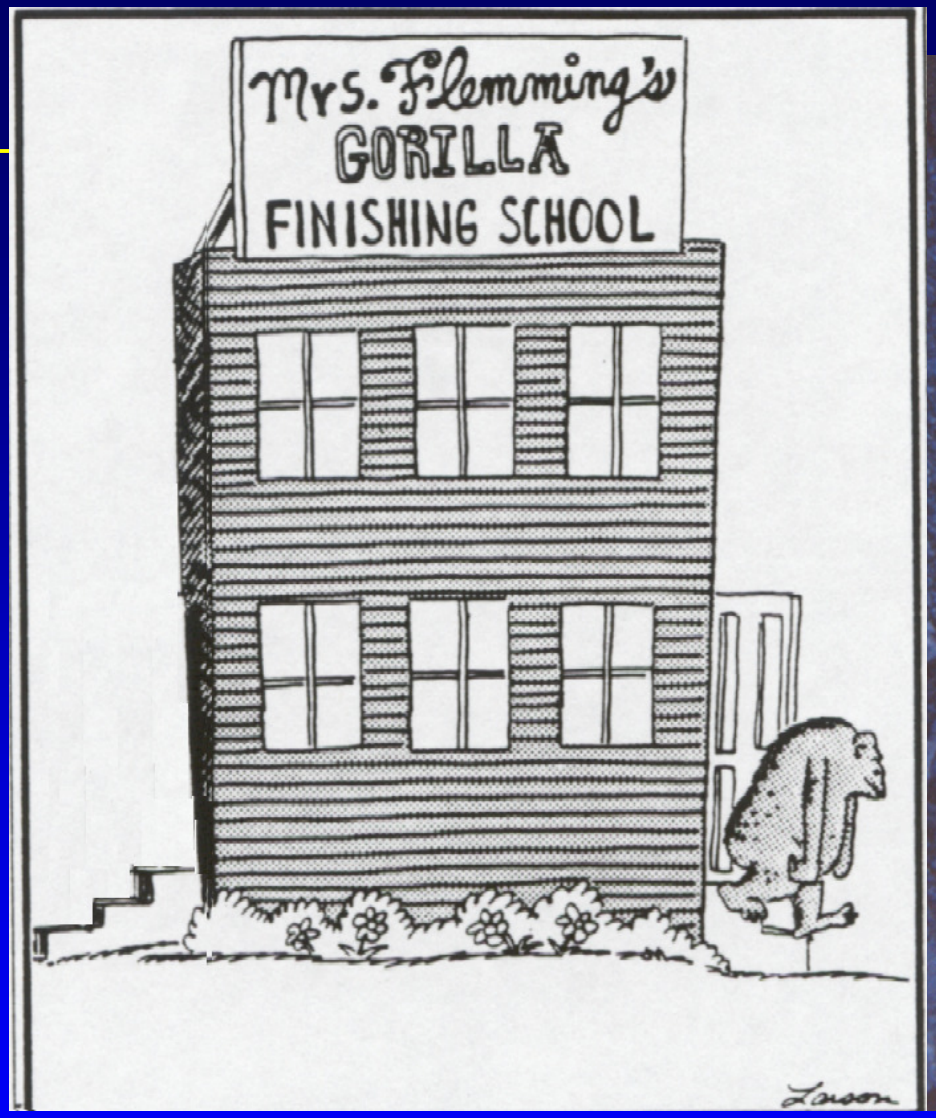
- Sign long term contracts
- Evaluate foreign & Domestic coal sources
- Invest (Buy/JV) in mines & preparation plants Domestic & Globally (USA New Projects=2.5 mt LVM; 3.5 mt MVM; Australia=50 mt increase planned; few more in Canada)
- JV coke plants in other countries
- Increase Blast Furnace PCI to maximum limits
- Use Low Rank Poor Coking Coals in the blend (maximize low value carbon materials; adopt new methodologies)
- Adopt continuous coke making technologies that uses Low Rank Poor Coking Coals
- Investigate "Think Out of Box" Technologies
- Invest in R&D

IN THE SCHOOL OF COKE MAKING

I entered as a child!

IN THE SCHOOL OF COKE MAKING

I became one with the team!



Overall, I triumphed!

Now, I am ready to start a new journey!

REFUGEES

Like the dews

They fell over

petals and thorns

And

Chased the dreams of a butterfly.

-Hardarshan Valia

THANKS

- To my colleagues from the Coal & Coke Industry
- To Gary Larson, the creator of "The Far Side" whose cartoons are reproduced in this lecture, for reminding us that "Work is Fun!"