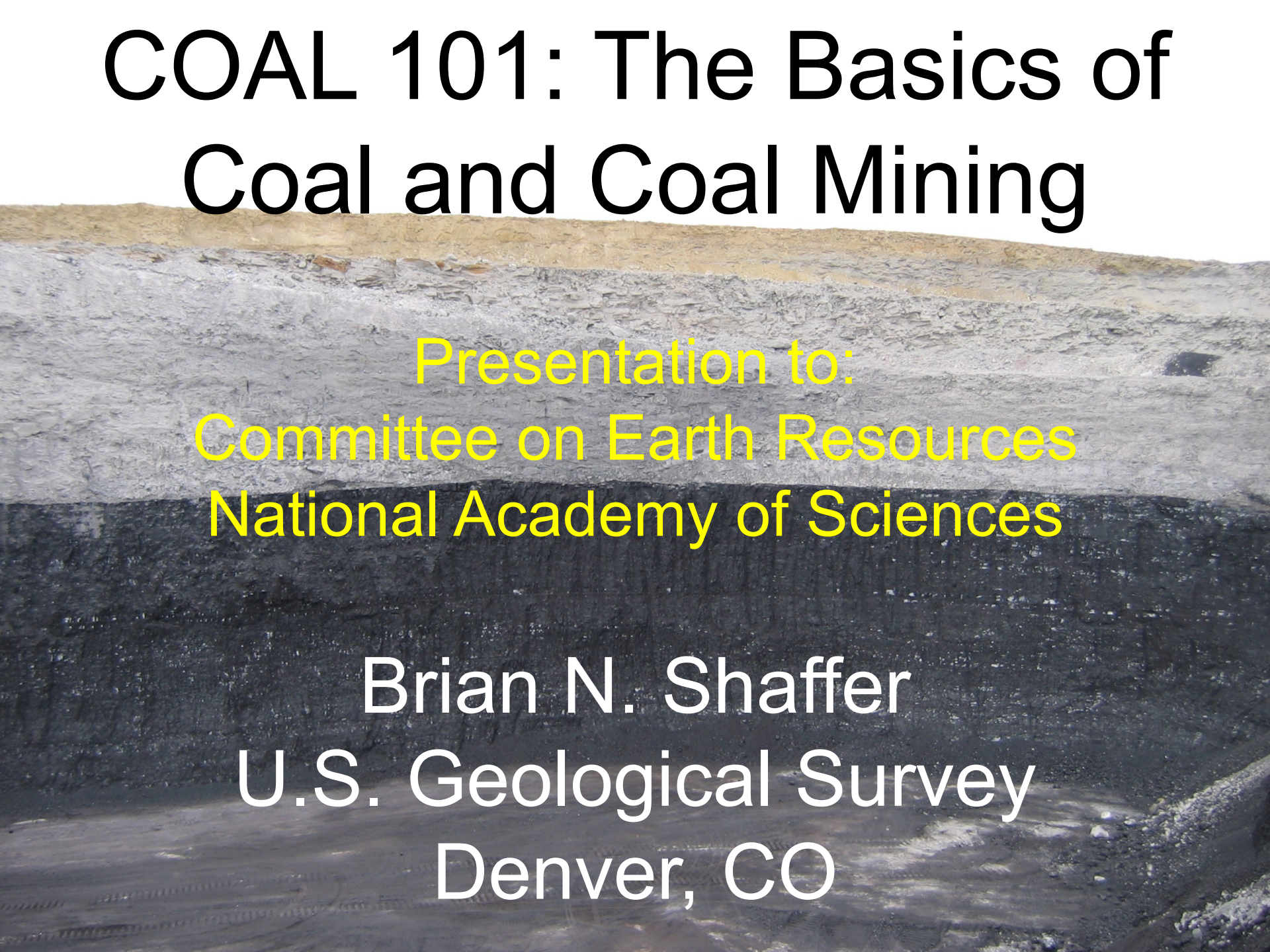
COAL 101: The Basics of Coal and Coal Mining



Presentation to:
Committee on Earth Resources
National Academy of Sciences

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U.S. Coal Resources & Reserves Assessment Project

Central Energy Resources Science Center

- Assess remaining coal resources of the Nation – on a regional basis.
- Estimate remaining coal reserves of the Nation – utilizing economic models and current spot market prices.
- Determine coal resources and reserves under Federal lands – as mandated by Congress.
- Serve as technical experts on coal for Federal agencies – BLM, EIA, State Department, etc.
- Assist with the compilation of coal drill hole data into the National Coal Resources Data System (NCRDS).

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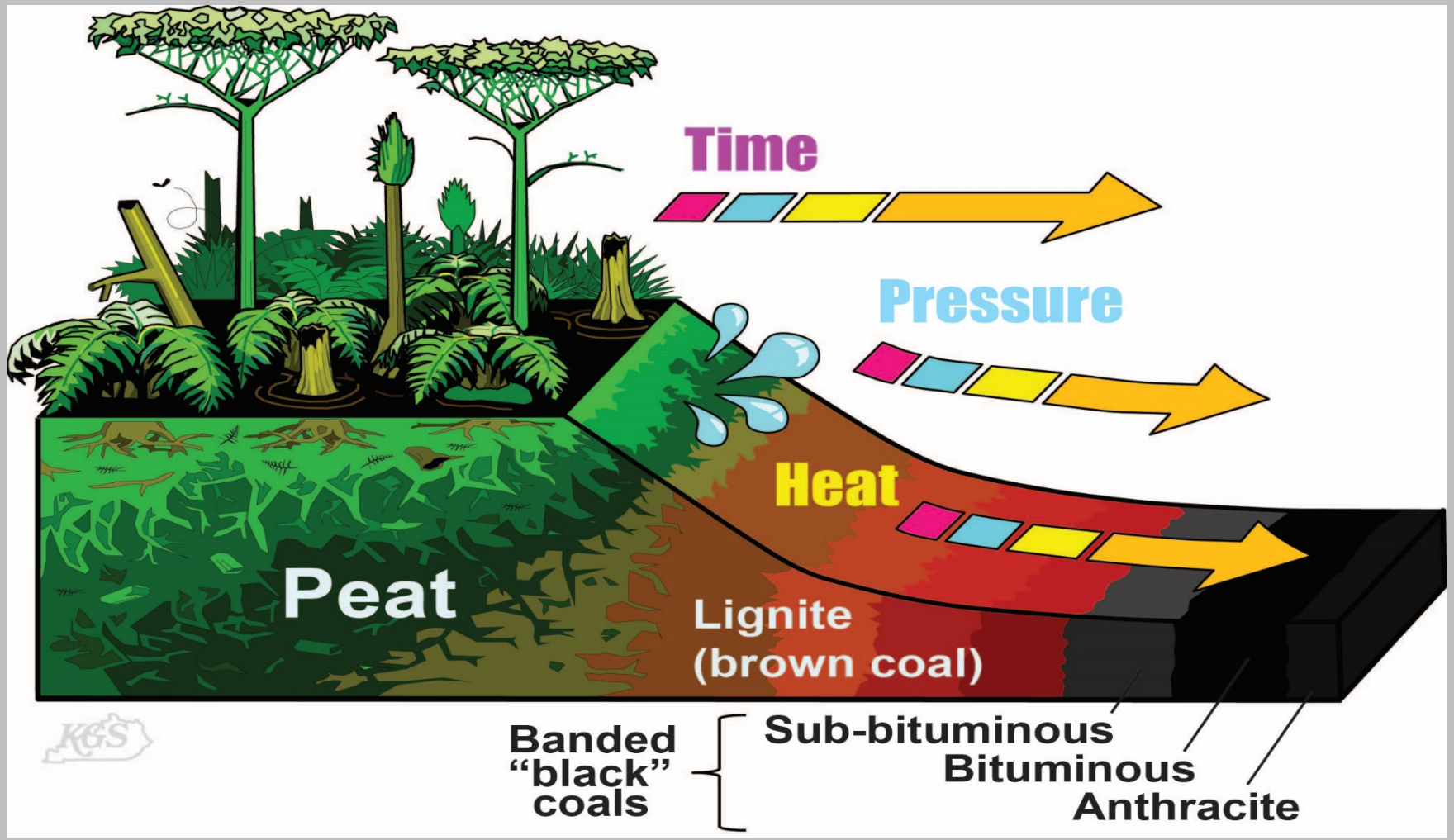
Stages of Coalification



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Graphic courtesy of the Kentucky Geological Survey

U.S. Coal Rank Classification System

Peat → Lignite → Subbituminous → Bituminous → Anthracite

Heat and/or pressure increasing →

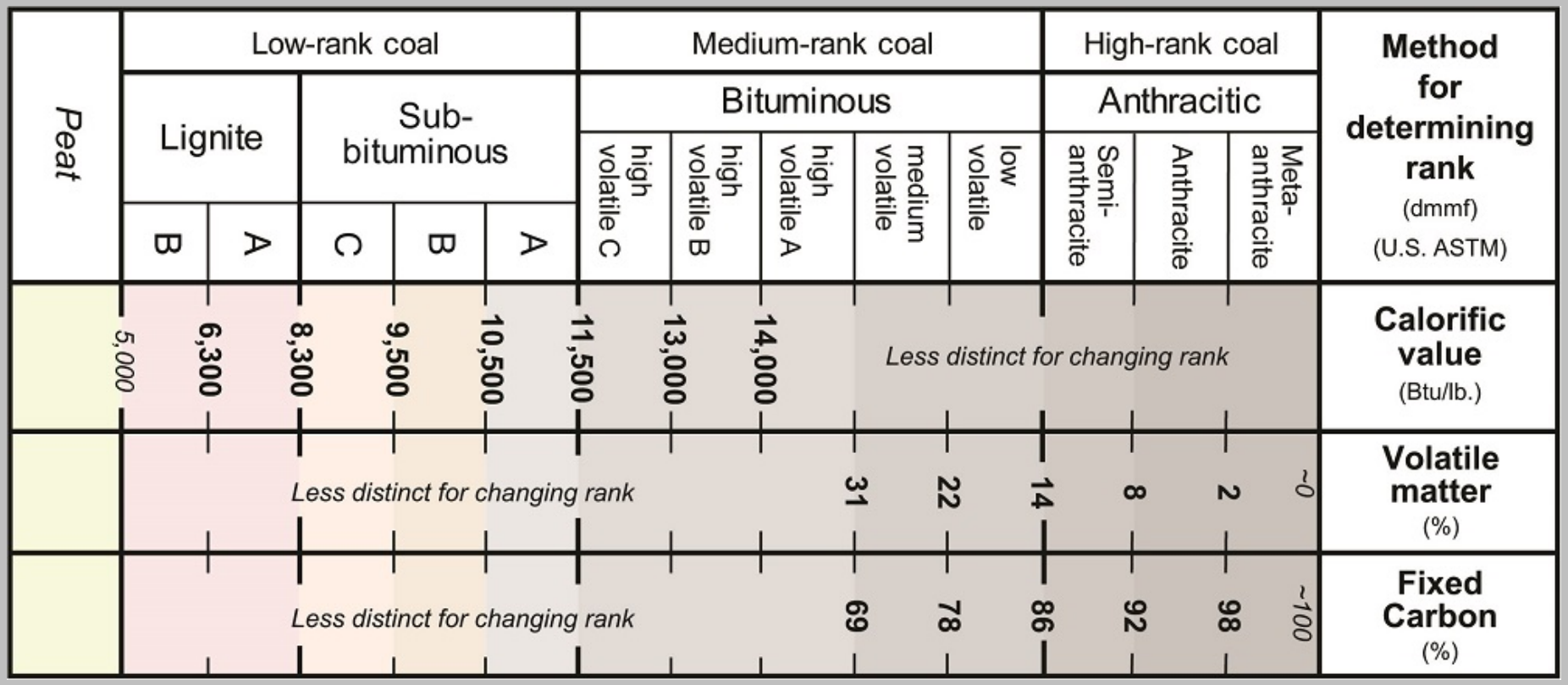

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Table courtesy of the Kentucky Geological Survey

Coal – What is it used for?

- Generation of electricity (steam coal)
  - a wide range of coal ranks and coal qualities can be utilized
  - steam coal products tend to be used regionally
- Steel production (metallurgical coal)
  - used to produce coke (carbon) – combined with iron ore and limestone to produce steel
  - coal quality parameters can be fairly tight:
    - low volatile matter content (15%-40% - bituminous coals)
    - low sulfur content
    - low phosphorous content
    - low chlorine content
    - low alkali content
- Other minor uses – specialty products, chemicals extractions, and industrial and residential heating

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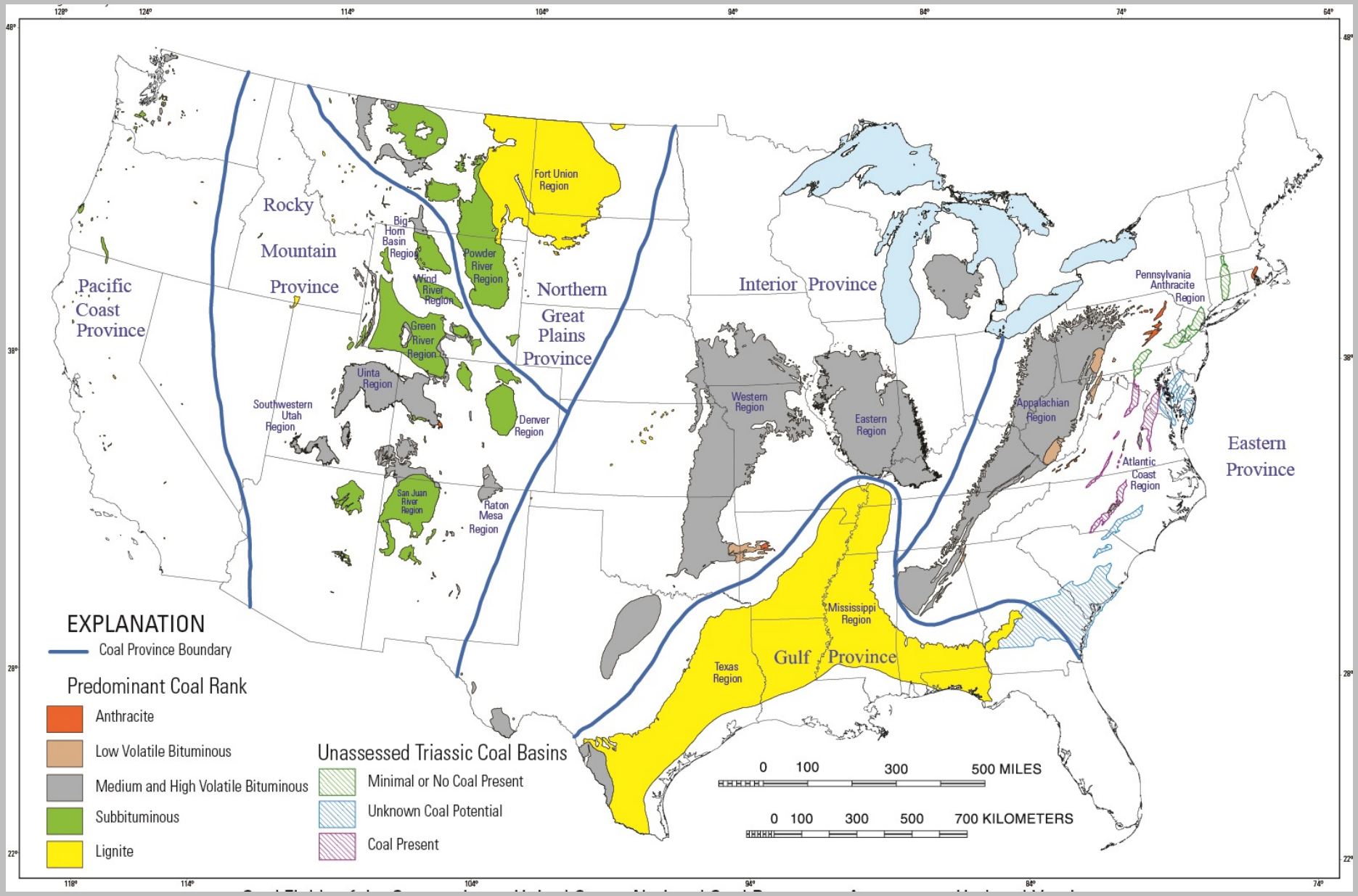
Map showing coal fields of the United States



East, J.A., 2013, Coal fields of the conterminous United States-National Coal Resources Assessment updated version: U.S. Geological Survey Open-File Report 2012-2015, one sheet, scale 1:5,000,000.

Coal Production – Eastern United States

- Eastern U.S.:
  - Produces high volatile, mid- to high-sulfur steam coal:
    - Northern Appalachian Basin
    - Illinois Basin
    - Central Appalachian Basin
  - Produces low- to mid-volatile, low-sulfur metallurgical coal:
    - Central Appalachian Basin
    - Southern Appalachian Basin
    - Northern Appalachian Basin.
  - Produces lignite for steam coal:
    - Gulf Coast Region
    - Texas lignite belt
  - Produces anthracite coal for industrial and residential heating:
    - Northern Appalachian Basin

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Coal Production – Western United States

- Western U.S.:
  - Produces low-sulfur, low-BTU, subbituminous steam coal:
    - Powder River Basin – Wyoming, Montana
  - Produces low-sulfur, high-volatile bituminous steam coal:
    - Yampa coal field and Piceance Basin – Colorado
    - Uinta region – Utah, Colorado
  - Produces low-sulfur, low-BTU lignite steam coal:
    - Williston Basin – North Dakota, Montana
  - Potential production of low-sulfur metallurgical coal:
    - Uinta and Kaiparowits regions - Utah
    - Raton Basin – Colorado, New Mexico

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Coal Mining Methods

- Surface mining – involves stripping off overburden to access coal resources. Overburden is the layers of soil and rock that overlie a coal bed.
  - Contour mining
  - Mountaintop removal mining
  - Area mining
  - Auger mining
  - Highwall mining

- Underground or deep mining - extracting coal resources from beneath the earth's surface using a series of tunnels, adits, shafts, or other excavations.
  - Room and pillar mining
  - Longwall mining

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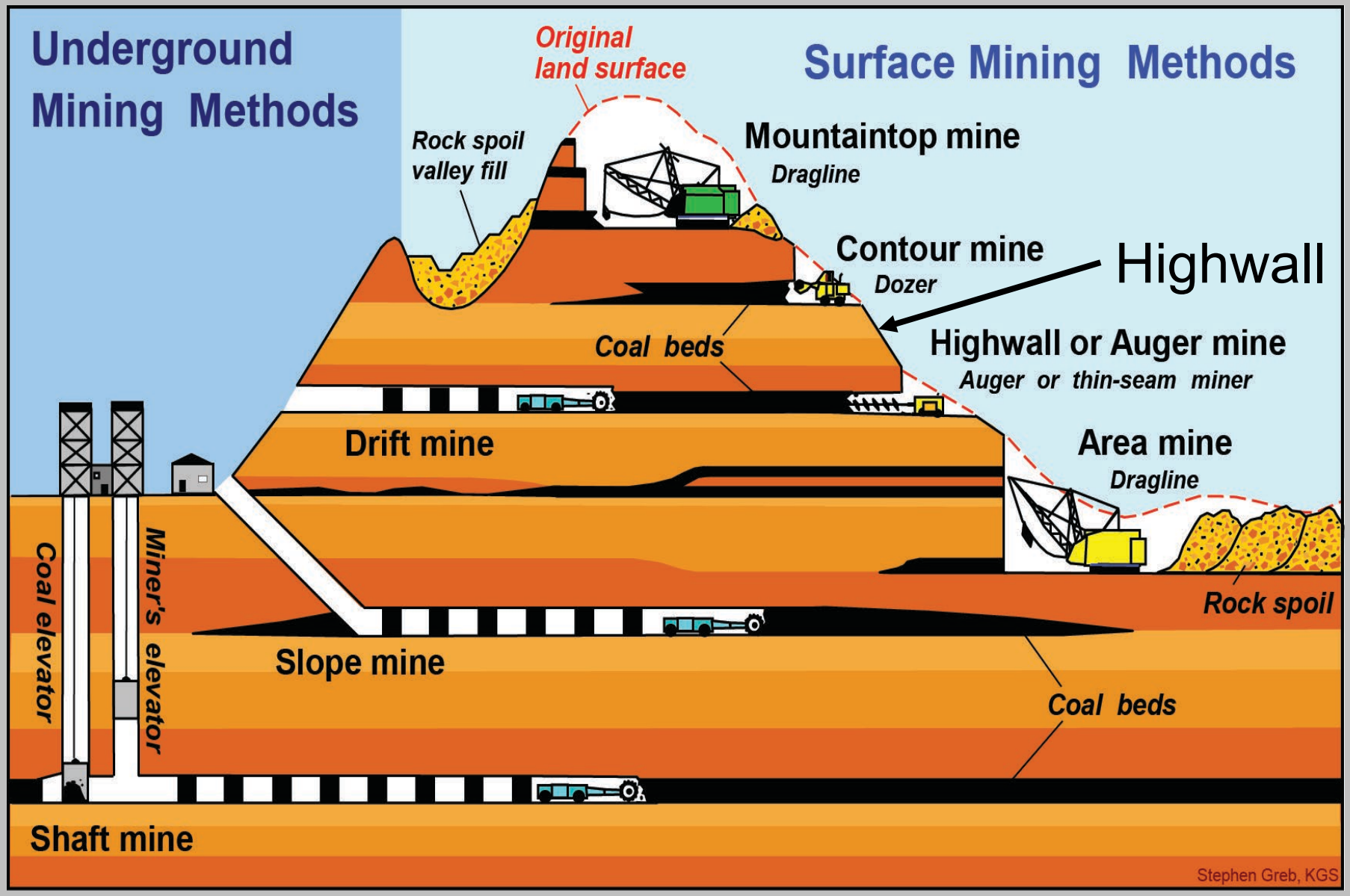
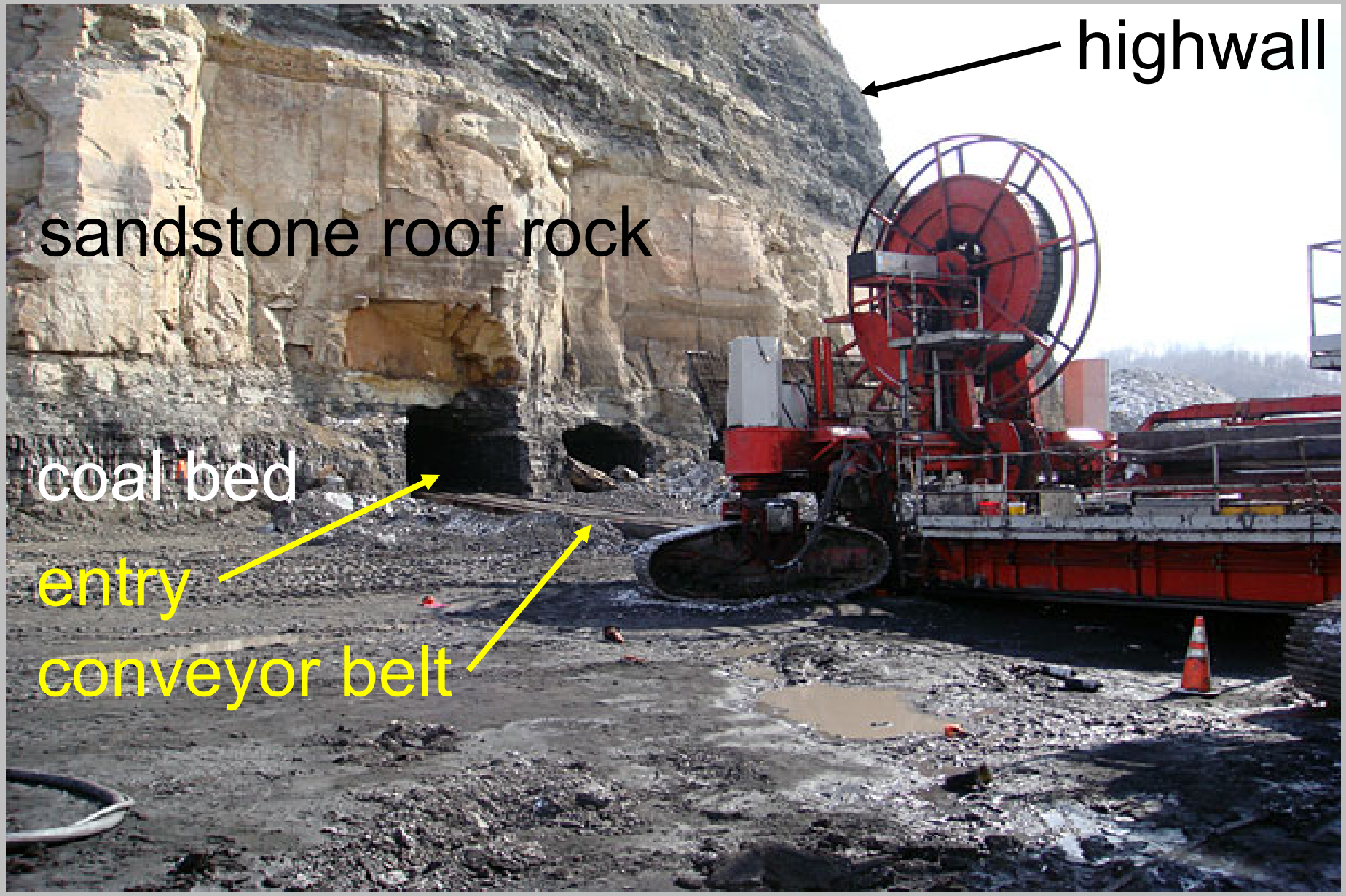
Examples of Different Coal Mining Methods



Graphic courtesy of the Kentucky Geological Survey

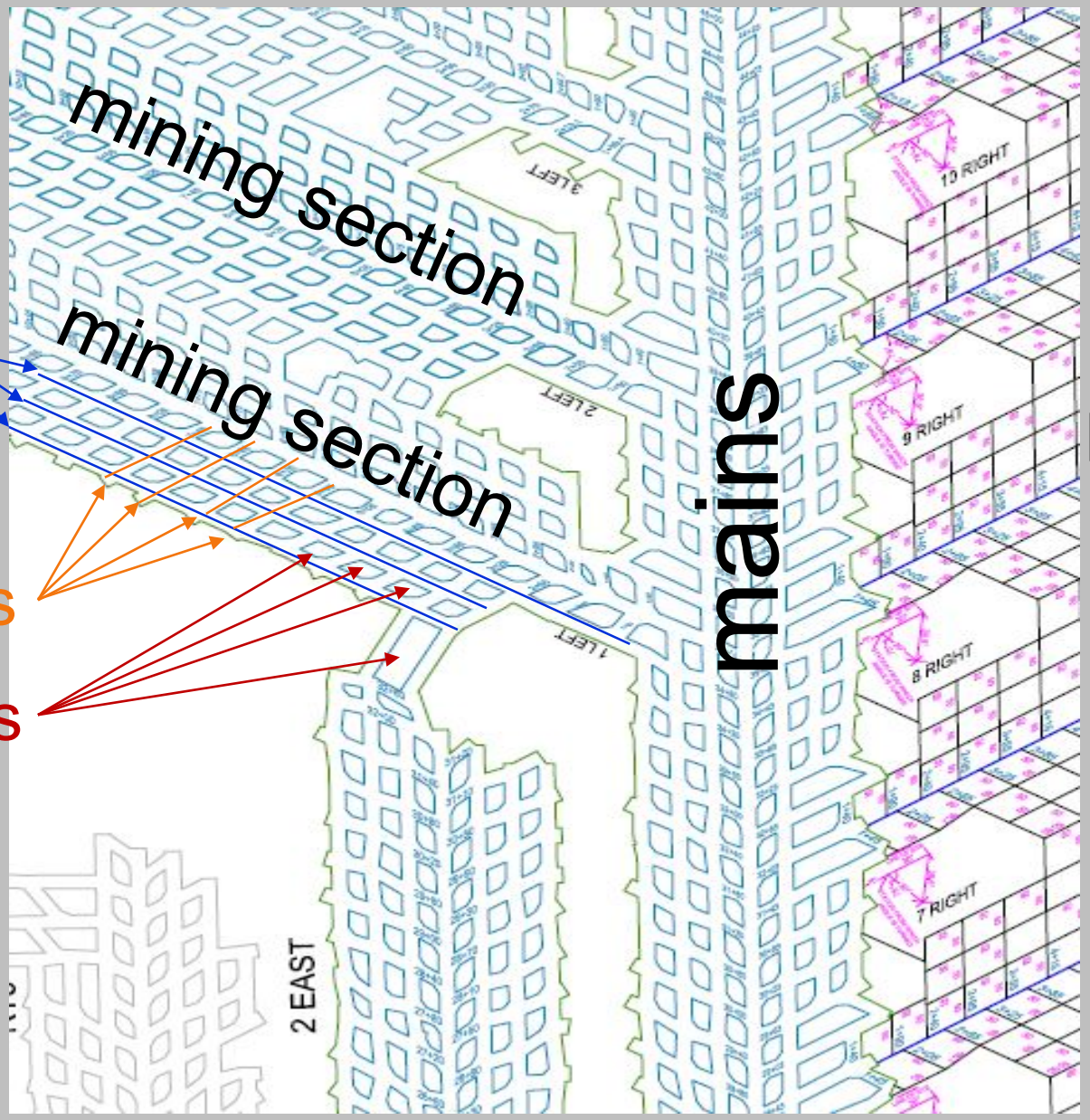
Example of Highwall Mining – Cent. App.



Area Surface Mining – Powder River Basin

Area Surface Mining – Powder River Basin

Room and Pillar Mining Example



Rooms

Cross-cuts

Coal pillars

Projected future mining sections

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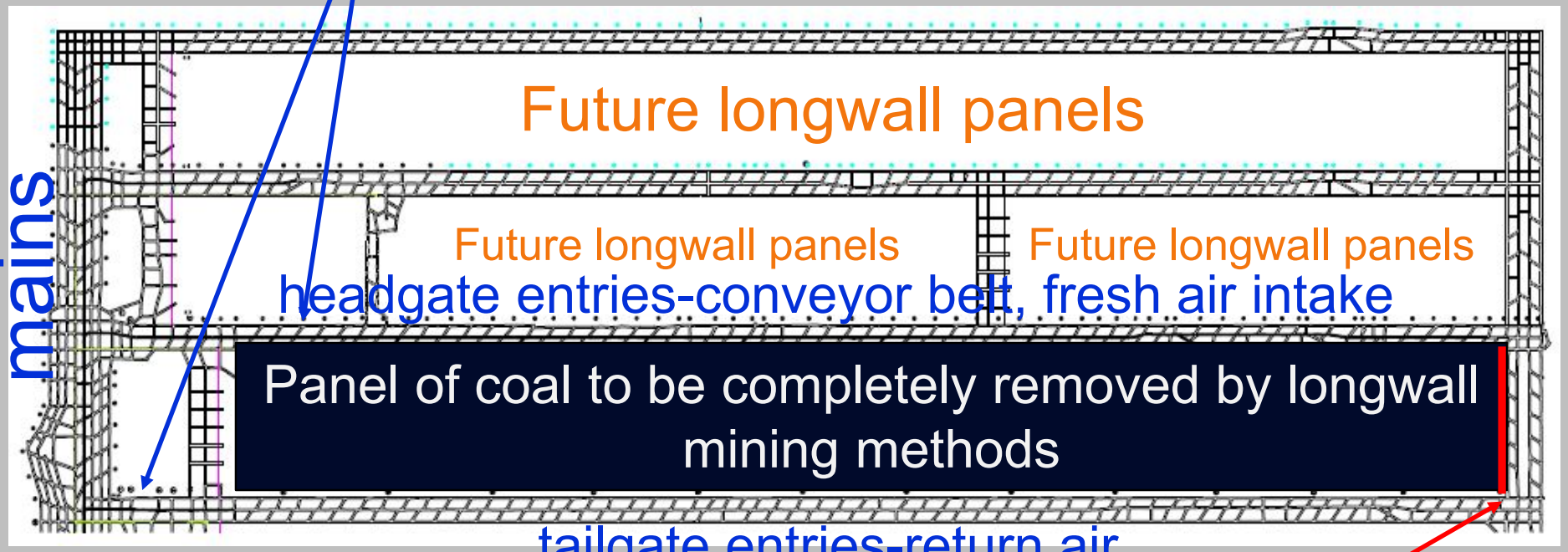
Room and Pillar Mining - Continuous Miner

Longwall Mining Example



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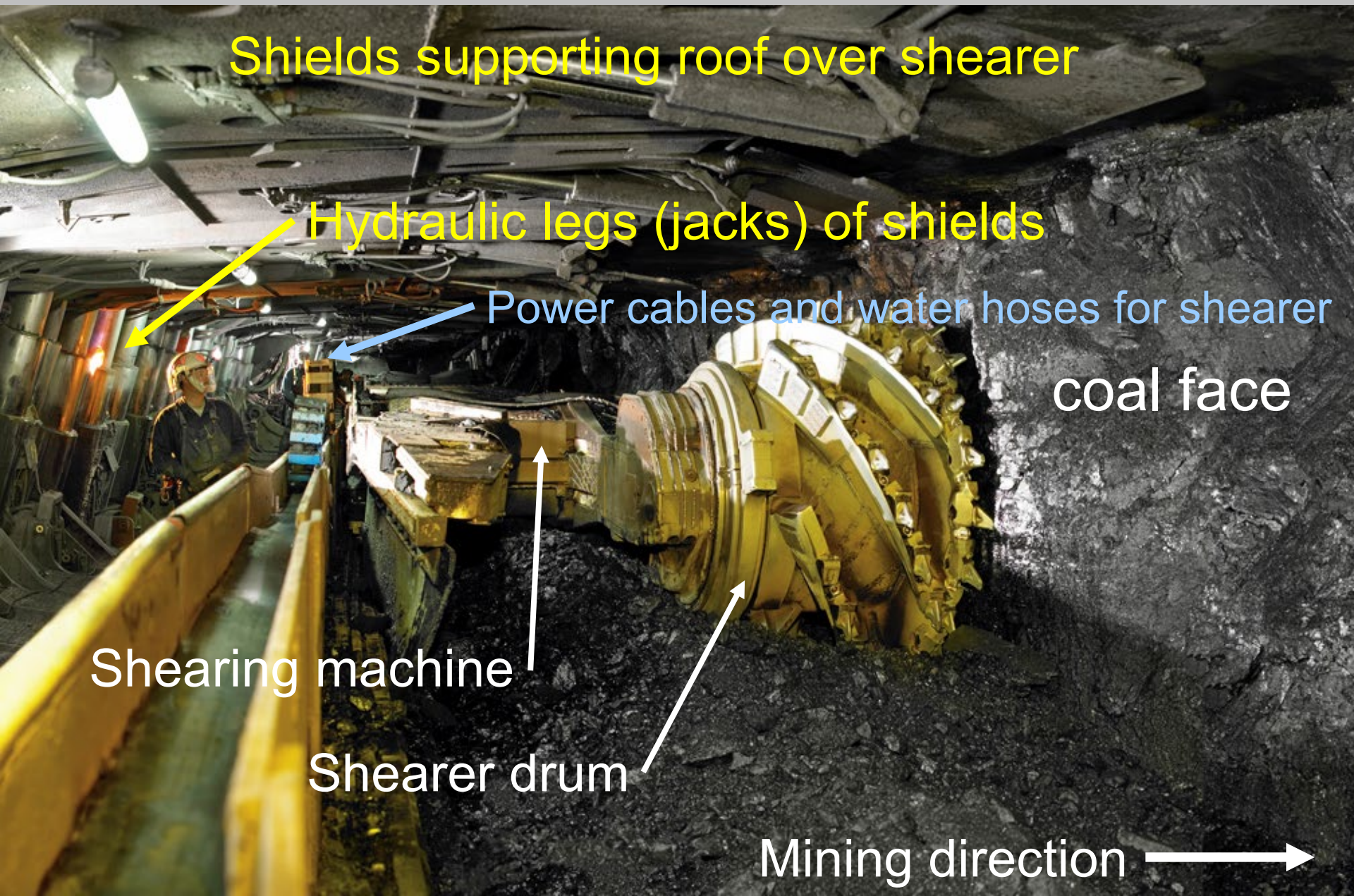
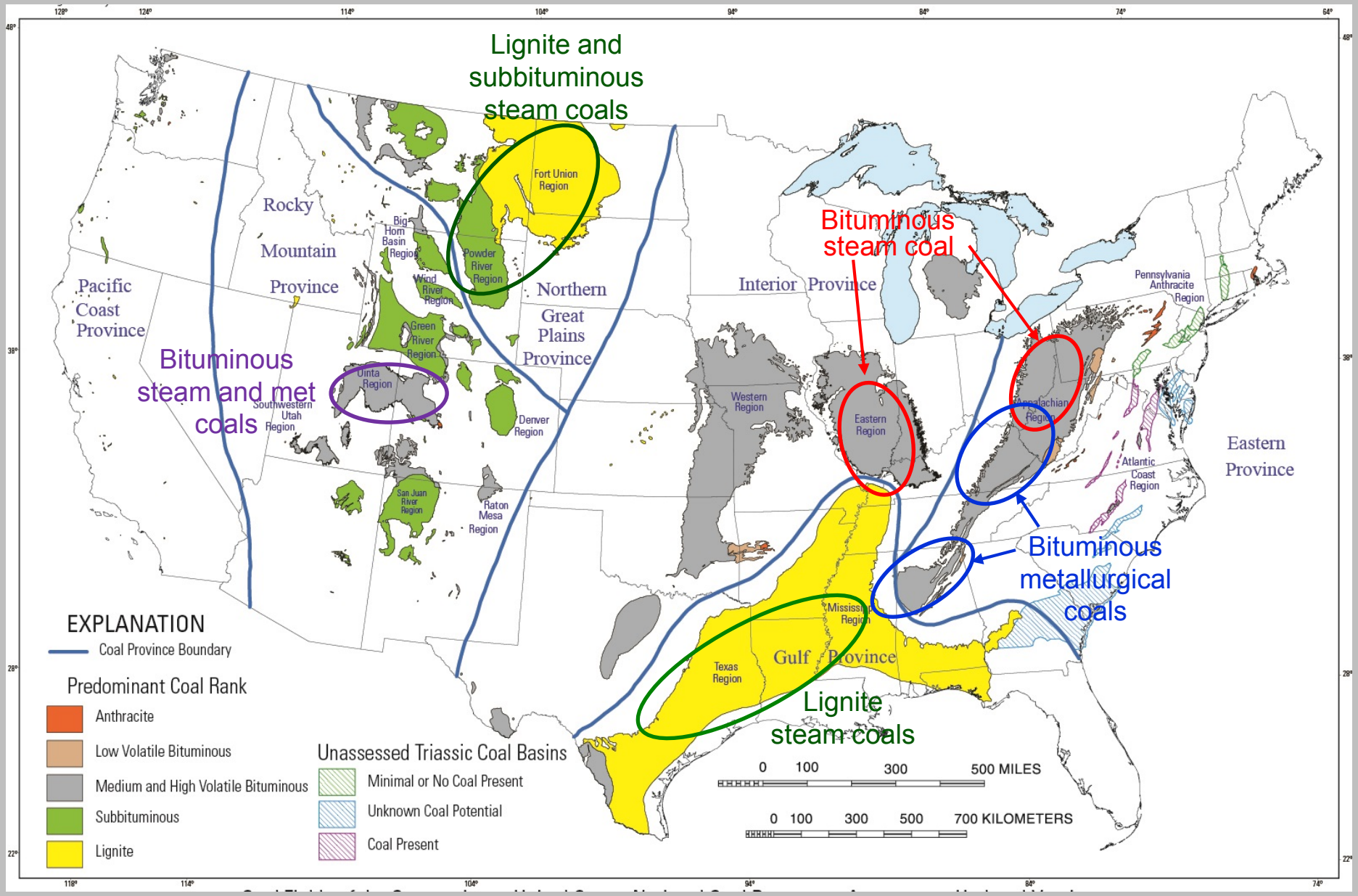
Longwall Mining Equipment



Future recoverable coal resources and reserves



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Diminishing Coal Resources and Reserves

- Basins or regions with concerns for diminishing resources and reserves:
  - Central Appalachia – shallow, above drainage coal reserves nearly exhausted; remaining reserves are deeper or limited in areal extent and more difficult to mine.
  - Northern Appalachia – most of the prime reserve blocks are being or have been mined; remaining reserves are thinner and many contain geological challenges.
  - Illinois Basin – remaining reserves are thinner, limited in areal extent, or contain geological challenges.
  - Powder River Basin – low cost, low stripping ratio coal are nearly gone; increasing stripping ratios are increasing mining costs.
  - Uinta and Green River Basins – nearly all easily accessible reserve blocks have been mined; remaining reserves are deeper or contain geological challenges.

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Opportunities Through New Technology

- How do you deep mine very thick coal beds (PRB-type coals)? Multiple, stacked longwalls? Block caving? Room and pillar with high pillars (limestone mine-style)?
- Can increased automation and remote control allow mining of thin coal beds or those with dangerous geological challenges?
- Can better or more robust ground control and ventilation methods allow mining at deeper depths or in challenging geological conditions?
- Can improvements in clean coal technology (CCT) allow for increased utilization of all coal types?

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Coal Resources and Reserves Classification

- Coal resource classifications – progressively refined categories where coal resource values are calculated by subtracting resources lost due to geologic conditions, land-use restrictions, and/or technological limitations.
  - Recoverable resources – coal resources that can be mined regardless of cost with currently available technologies, after subtracting coal resources lost to previous mining, burn or weathered zones, geological limitations, land-use restrictions, and excessive depth or stripping ratios. This classification is equivalent to *EIA's Demonstration Reserve Base (DRB)*.
  - Reserves – the portion of recoverable resources where the cost to extract the coal is less than the current economic value of the coal. By USGS definition, reserves values will fluctuate over time, based on current market prices. This classification is not equivalent to the *EIA's Estimated Recoverable Reserves (ERR)*, which are calculated from the DRB using an estimated recovery value. Also, ERR values are not adjusted for current market prices.

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Coal Resources Calculation Example

POWDER RIVER BASIN COAL RESOURCES AND RESERVES		
COAL RESOURCES ASSESSMENT CLASSIFICATION	**TONS (billions of short tons)**	**PERCENT OF ORIGINAL RESOURCES**
ORIGINAL RESOURCES	1156	100%
subtract - previously mined or sterilized coal *subtract - weathered, burn, or clinker areas along outcrops*		
REMAINING RESOURCES	1148	99%
subtract - geological constraints (coal missing, coal too thin) *subtract - environmental or societal restrictions* *subtract - technical restrictions*		
AVAILABLE RESOURCES	179	15%
subtract - coal too deep *subtract - stripping ratios too high* *subtract - unable to mine due to mining technology limitations*		
RECOVERABLE RESOURCES	162	14%
subtract - cost to extract greater than value of coal		
RESERVES	25	2%

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From Luppens and others, 2015

COAL 101 – The Basics of Coal and Coal Mining

Questions or Discussion?

Appendices

- Contain additional information on:
  - Coal and the coalification process
  - Coal ranks
  - Mining methods – surface mining
  - Calculating stripping ratios
  - Mining methods – underground mining
  - Room and pillar versus longwall mining
  - Coal mining methods and costs

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What is coal?

- Readily combustible rock
  - contains >50% carbonaceous material + inherent moisture by weight
  - contains >70% carbonaceous material + inherent moisture by volume
- Formed from plant remains that have been:
  - rapidly buried by sediments to prevent normal decay and rotting
  - compacted by the weight of overlying sediments – squeezing out water and reducing volume
  - chemically altered and metamorphosed by heat and/or pressure due to burial or igneous activity.

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Coalification

- Coalification is a process where organic and inorganic compounds are changed chemically and physically over time by heating and/or pressurization.
- Heating and pressurization usually result from increasing depth of burial of the plant material by overlying sediments, but can also be induced locally by igneous activity.
- Coalification is a continuing process where increasing heat and/or pressure increases the degree of coalification. The degree of coalification can't be reversed.
- The stages of coalification are classified as coal RANKS.

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Coal Rank

- Degree of coalification or alteration of coalified plant material due to increasing temperature and/or pressure.
- Coal rank classifications are based on the chemical analysis of coal:
  - Fixed carbon – the non-volatile carbon content of a coal sample that remains after moisture, ash, and volatile matter are removed.
  - Volatile matter – non-water gas content of a coal sample released when the sample is heated to 950 degrees Celsius in an oxygen-free environment.
  - BTU – the calorific value of the coal, measured by the amount of energy produced from a unit weight of coal when combusted in oxygen.

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Coal Mining Methods

- Surface mining – involves stripping off overburden to access coal resources. Overburden is the layers of soil and rock that overlie a coal bed.
- Surface mining is limited by stripping ratios:
  - ratio of the volume of overburden (in cubic yards) to the quantity of coal (in short tons).
  - the limit of surface mining (maximum economic stripping ratio) is reached when the cost of removing the overburden is equal to or greater than the value of the coal.
  - once the maximum stripping ratio is reached, mining will be abandoned or the mining method must be changed.

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Coal Mining Methods (cont.)

- Surface mining methods:
  - contour mining – used in steep, hilly terrain, following the contour of the hill; maximum economic stripping ratio is reached quickly.
  - mountain top removal – used on hill tops where the stripping ratio of the entire hill top is less than the maximum economic stripping ratio. Overburden is placed in adjacent valleys.
  - area mining – used in areas, such as the Powder River Basin, where the land surface is relatively flat and stripping ratios increase gradually with depth.
  - auger mining – used in conjunction with contour mining; coal resources that are beyond the maximum economic stripping ratio are extracted using augers that are drilled into the highwall.
  - highwall mining – similar to auger mining; coal resources are extracted using a remote control mining machine and removed from the highwall by coal conveyor units.

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Calculating Stripping Ratios

- **A four foot coal bed is overlain by 75 feet of overburden:**
  - calculate overburden volume using an area of 1 yard long by 1 yard wide:

    75 ft./3 ft. per yard = 25 yards depth

    volume = 25 yds. depth x 1 yd. wide x 1 yard long

    volume = 25 cubic yds. of overburden
  - calculate volume of coal in 1 yd. by 1 yd area (convert yds. to ft.)

    volume = 3 ft. wide x 3 ft. long x 4 ft. thick

    volume = 36 cubic feet
  - calculate quantity of coal, using a density of 80 lbs./cubic ft.

    quantity of coal = 36 cubic ft. x 80 lbs./cubic ft.

    quantity of coal = 2,880 lbs. or 1.44 short tons
  - calculate stripping ratio:

    stripping ratio = 25 cubic yds overburden/1.44 short tons of coal

    stripping ratio = 17.36

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Coal Mining Methods (cont.)

- Underground mining methods – extracting coal resources from beneath the earth's surface using a series of tunnels or excavations.
- Coal is extracted using mechanized mining machines and removed, in most cases, via conveyor belts to the surface.
- The roof (ceiling) and ribs (walls) of the mine are supported (held up) and stabilized by a variety of roof bolts, standing supports, and metal and nylon mesh.
- Underground coal mines must be ventilated through the use of high-pressure fans in order to remove explosive or noxious gases and coal dust.
- All exposed coal surfaces in an underground mine must be coated with an inert rock dust (usually limestone) to prevent the ignition and propagation of coal dust explosions.

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Coal Mining Methods (cont.)

- Underground mining methods:
  - room and pillar mining – coal is extracted by driving a series of entries (rooms) that are connected periodically by perpendicular entries (cross-cuts). The blocks of coal that remain between the entries and cross-cuts are known as pillars.
    - retreat mining – a type of room and pillar mining where the remaining coal pillars are partially or completely extracted after mining in an area is completed and the equipment is withdrawn (retreated).
    - super section mining – a type of room and pillar mining where multiple mining units drive room and pillars in conjunction with one another and the extracted coal is all removed via a single conveyor belt.

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Coal Mining Methods (cont.)

- longwall mining – a mining method where a large block (panel) of coal is completely removed by a mechanical shearing machine.
  - The sheared coal falls onto a conveyor chain and is carried off of the mining face and transferred to a conveyor belt.
  - The roof above the shearer and the face chain is supported by large hydraulic roof supports called shields. There may be more than 200 shields on a longwall face, depending on the width of the face and the widths of the individual shields.
  - The shearer works back and forth cutting the coal across the mining face. Each trip down the mining face is called a pass.
  - After each pass, the shearer and face chain advance, the shields are moved forward, and the roof collapses into the area that is vacated by the equipment.
- Room and pillar mining methods are used to access the panel of coal that will be mined by the longwall equipment.

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Room and Pillar vs. Longwall

- Room and pillar methods:
  - used to extract limited or less extensive coal reserves
  - lower initial capital costs – lower cost equipment; fewer pieces of equipment
  - allows mining planning to be flexible to adjust to adverse geological conditions or to access areas of favorable coal thickness or quality; usually requires less exploration drilling
  - lower productivity (less tons/manhour worked)
  - higher production costs (more $/ton produced)
  - favorable method for producing metallurgical coal (higher value coal/ton)
  - can produce steam coal for local consumption (lower transportation costs)

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Room and Pillar vs. Longwall

- Longwall mining methods:
  - used to extract large, laterally extensive coal reserves with limited adverse geological conditions
  - high initial capital costs – higher equipment costs due to both more complex equipment and more pieces of equipment
  - mine planning is not flexible; once longwall panels are laid out and developed, it is very difficult to adjust mine plans to deal with adverse geological conditions; requires closely spaced exploration drilling
  - higher productivity (more tons/manhour worked)
  - lower production costs (less $/ton produced)
  - favorable method for producing large volumes of steam coal (lower value coal/ton)
  - premium profitability if metallurgical coal can be produced by longwall methods.

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Coal Mining Methods and Costs

- Surface mining:
  - Powder River Basin:
    - utilizing area mining, including truck-and-shovel operations.
    - lower value of coal ($9.00 - $12.00/per ton) restricts stripping ratios to <5:1 in order to keep mining costs low.
  - Appalachian Basin:
    - utilizing contour mining and mountain top removal mining.
    - may utilize auger or highwall mining once stripping ratios exceed economic limit to supplement production and maximize reserve recovery.
    - higher value of coal ($90+/ton for met coal or $50-$75/ton for steam coal) allows for stripping ratios of over 20:1.

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Coal Mining Methods and Costs

- Underground mining:
  - Room and pillar mining:
    - lower productivity and lower volumes result in higher mining costs (up to $80/ton).
    - mining restricted to premium steam coal or metallurgical coal products.
  - Longwall mining:
    - high productivity and high volumes result in lower mining costs (usually less than $40/ton)
    - mining produces steam coal and opportunity sales for metallurgical coal, specialty products, and chemicals extractions.

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