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PRACTICAL APPLICATION OF THE UNITED NATIONS INTERNATIONAL FRAMEWORK CLASSIFICATION FOR RESERVES/RESOURCES

COAL RESOURCE ASSESSMENT AT THE US GEOLOGICAL SURVEY AND THE UNITED NATIONS FRAMEWORK CLASSIFICATION FOR RESERVES/RESOURCES

(Submitted by the Government of the United States of America) *

Abstract: This report is one of a series entitled "Practical Application of the United Nations Framework Classification for Reserves/Resources " and it is specifically related to the National Coal Resource Assessment of the United States of America. Of all the sources of energy produced in the United States, coal is the largest. The majority of the electricity in the USA (56%) is produced from the burning of coal, and coal will continue to be the dominant source for electricity for many years to come. The amount of coal produced in the USA is currently at an all time high and will continue to increase. Understanding this indigenous resource is vital to the future economic and environmental well being of the Nation and accurate resource assessments depend upon accurate analytical methods. The categories of resources and reserves used in this National study and reported in the associated USGS publications may be readily and directly correlated with the terms and codes of the United Nations Framework Classification.

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I. ASSESSING COAL RESOURCES AT THE U. S. GEOLOGICAL SURVEY

1. An application of modern computer techniques to classical coal resource analyses.

Current coal resource assessment activities at the United States Geological Survey (USGS) are measuring the quantity, characterizing the quality, and evaluating the availability and recoverability of those coal resources and reserves that will supply much of the needs for fossil fuel in the U.S. in the twenty-first century. The scales on which the studies are conducted vary widely; from areas as small as a single 7 ½ minute quadrangle (approximately 150 square kilometres [60 square miles])) to regional studies that include basins extending over several states.

Current assessments differ in methodology from all previous USGS assessments in that the information is stored, manipulated, and analysed in digital form. All current USGS assessments, regardless of scale, make use of geographically referenced data; that is, their position in the earth is known. The digital data are then manipulated and analysed by means of a Geographic Information System (GIS). The term GIS refers to a computer system used to collect, store, update, manipulate, analyse, and present the results of information concerning, in this case, coal deposits that are geographically located on the earth's surface and within the uppermost part of

The basic, underlying concepts of calculating volume and tonnage are the same concepts that mining engineers and geologists have used for many years, but the ability to manipulate, evaluate, and then re-evaluate the data and thereby to respond to a large range of questions concerning the nature of the resources and reserves is new. This flexibility of analyses is enabled by utilizing the GIS and its ability to process large amounts of data in a relatively short time.

2. Coal assessments - from resources to reserves.

The current study, the National Coal Resource Assessment (NCRA), is identifying those resources that will provide the greater portion of the Nation's coal during the next three decades. For the purposes of this study, the Nation has been divided into five principal coal producing regions, as shown in Figure 1. Teams, composed of geologists, geochemists, and GIS experts are investigating the resources of each region; one team for each region. The scientists working in each region have specific knowledge and expertise in those areas and are therefore capable of evaluating the accuracy of the data being collected, conducting resource analyses, and evaluating the validity of the products of the assessment in their region.

Until recent years, the estimates of coal reserves in the United States did not address the amount of coal made unavailable for production because of environmental, land use, technological, and geologic constraints. The Coal Availability and Coal Recoverability projects at the USGS and the former U.S. Bureau of Mines were initiated in response to these needs, and in cooperation with geological agencies in the principal coal producing states. These studies address these issues and (1) identify and delineate the current major restrictions on the availability of coal resources; (2) estimate the amount of remaining coal resources that may be available for

development under those constraints; (3) estimate the amount of coal that can be economically extracted and marketed, and (4) identify possible social and economic disruptions that occur within local and regional economies as coal resources are exhausted.

Regional studies are done under the aegis of the National Coal Resource Assessment (NCRA) and the results obtained in all of the individual regions will be aggregated into a national summary. The quantities of coal in these investigations are **coal resources**; coal that has some potential for future production, but additional economic studies must be done in order to determine the economic feasibility of producing those resources at the present time. **Coal reserves,** the subset of the resource that can be produced at a profit under current market conditions, are identified as a result of the Coal Availability and Coal Recoverability studies (Eggleston and others, 1990, Rohrbacher and others, 1993) Because of the data-intensive nature of Coal Availability/Coal Recoverability, these studies were initially conducted in relatively small areas (hundreds of square kilometres) and where abundant data were available. The results were then extrapolated to entire coal basins or coal producing regions. Coal Availability studies have generally been designed to sample approximately four percent of the total area of a coal producing region.

3. Accurate data are vital to accurate coal resource assessments.

The total coal endowment (all of the coal in the ground) of the United States is large and the locations of all of the major coal basins are known. Coal that will be burned to provide the Nation's electric energy during the twenty-first century will be produced from those known basins. Coal resource assessments are distinctly different from oil and gas resource assessments in that they do not require the analysts to predict the location and quantity of undiscovered resources. Current coal resource assessments are the results of the analyses based on measurements that have been made directly on the coals of interest. The most important and time consuming aspect of the coal resource assessment process is acquiring, validating, organizing, interpreting and entering the data into a digital data base so that the GIS can function accurately. The National Coal Resource Data System (NCRDS) of the U.S. Geological Survey is one major source of the geographically referenced data, as are data sets obtained from other Federal agencies, state geological surveys, and coal companies. Coal location and thickness are obtained from measurements taken from rock exposures in the field, in coal mines and from holes drilled during exploration for coal in advance of mining. Direct measurements of drill core and interpretation of geophysical logs, that represent some physical property of the rocks, are often used to determine thickness and extent of the coal bed. Some of the drill holes, measured sections, and coal mine data are used to produce cross sections and to provide a three dimensional view of the distribution of the coal deposit. Ultimately, a data base is developed and it forms the foundation for the resource analyses.

4. GIS readily manipulates digital data.

The GIS software, some of which were developed at the USGS and others which are commercial products, generate digital files (commonly called coverages) that can be plotted as maps showing the spatial distribution of the data. Coverages may represent a wide range of features, such as areal extent of the coal bed, the thickness of the coal over the area, the geological structure of the

coal bed, the depth to the coal from the surface, and the land ownership - whether Federal, State, or private. Covers used in calculating the resources of the Pittsburgh Coal bed in the northern Appalachian Basin have been published (Tewalt and others, 1997a, Tewalt and others, 1997b) and can be viewed on the USGS internet site. The amount of the coal resource is calculated utilizing the coverages. A volume of coal is obtained by combining the areal extent of the bed with the thickness. The volume is multiplied by the specific gravity of the coal, and the result is expressed in tons. The GIS can then be queried and new coverages made from the existing ones. For example, one can ask where there is coal that is more than 10 metres thick, at a depth of less than 70 metres, all under Federal ownership and the GIS, with the aid of someone expert in its operation, will produce a new coverage. The quantity of coal in the newly defined category is then readily determined. It is this ability to query the data sets and not be bound by the limits set by others that is one of the major strengths of the GIS. Potential users of the coal resource assessments will ask quite different questions of the system, depending on their specific interests; and geologists, mining engineers, county and state planners, Federal land managers, and policy makers will certainly have differing needs and interests.

5. Confidence limits of coal resources can be expressed.

The high quality data bases that are required in order to do coal resource analyses by GIS, lend themselves to other mathematical calculations. The coal resource assessment data bases are, for the first time, large enough and sufficiently well defined so that statistical methods can be employed in determining the confidence of the results. Experience gained in conducting the assessments has demonstrated that thickness variation in the coal bed(s) and the density of the data points are the primary sources of uncertainty of the final resource numbers. It is now possible to state confidence limits on many of the categories of resources reported.

II. U.S. GEOLOGICAL SURVEY COAL RESOURCE ASSESSMENTS APPLIED TO THE UNITED NATIONS FRAMEWORK CLASSIFICATION

1. Regional Assessments of coal resources and the United Nations Framework Classification

The Northern Rocky Mountains and the Great Plains region (Figure 2), one of the five regions currently being investigated in the National Coal Resource Assessment (NCRA) contains considerable resources of excellent quality, low sulphur coal. The Powder River Basin is the major coal producing basin in this region and most of the coal is mined from the Wyodak-Anderson coal zone. In 1997, Campbell County in Wyoming produced 234 million tonnes of coal from this coal zone. Only six countries in the world had national coal production that was greater than the coal produced in this one county. Coal resources have been determined in this region and reported in thickness categories, by depth of overburden, and by reliability categories. The reliability categories are 1) measured resources: coal within a radius of 0.25 miles (400 m) of a control point where the thickness of the coal has been measured; 2) indicated resources: coal within a radius of 0.25 mi (400 m) to 0.75 mi (1200 m) of a control point; 3) inferred resources: within a radius of 0.75 mi (1200 m) to 3 mi (5 km) of a control point; and 4) hypothetical resources: coal beyond a radius of 3 mi (5 km) from a control point. Resource estimates are reported in millions of short tons with two significant figures. The values are restated as tonnes

(1.0 tonne equals 1.102 short tons) in this paper. The resource data summarized here are from a recent CD-ROM publication of the U.S. Geological Survey (Professional Paper 1625-A, 1999)

Figure 3 displays the resource categories as they would appear on the McKelvey Box, the "standard" USGS basis (Wood and others, 1983). The resources of the Wyodak -Anderson coal zone in the Powder River Basin of Montana and Wyoming total 493 thousand million tonnes (USGS, 1999). Of this total, 8 percent is 'measured', 30 percent is 'indicated', 55 percent is 'inferred', and 7 percent is 'hypothetical'. None of the resources can be classified as reserves because only the most general of economic factors, depth and thickness, have been considered in their assessment.

The same values for the resources of the Wyodak-Anderson coal zone are shown on figure 4, the United Nations Framework Classification (UNFC) chart (United Nations Economic and Social Council, 1997). The four values are plotted in the geological study fields along the Feasibility Axis and in the boxes labelled 'Detailed Exploration' ("measured" in USGS terms), 'General " in USGS terms), 'Prospecting' ("inferred" in UGSG terms), and 'Reconnaissance' ("hypothetical" in USGS terms). The appropriate UNFC codes for these four categories are 331, 332, 333, and 334.

2. Coal availability and recoverability analyses and the United Nations Framework Classification

Data presented in the previous tables are coal resources; coal that has some potential for future production, but additional studies must be done in order to determine the economic feasibility of producing those resources. **Coal reserves,** a subset of the resource that can be produced at a profit under current market conditions, are identified as a result of the USGS and USBM Coal Availability and Coal Recoverability studies (Eggleston, and others, 1990; Rohrbacher and others, 1993). The Coal Availability and Coal Recoverability projects at the USGS and the USBM were initiated in response to the need for information as to the amount of coal made unavailable for production because of environmental, land use, technological, and geologic constraints.. The USGS, in cooperation with geological agencies in the principal coal producing states, (1) identify and delineate the current major restrictions on the availability of coal resources; (2) estimate the amount of remaining coal resources that may be available for development under those constraints; (3) estimate the amount of coal that can be economically extracted and marketed, and (4) identify the potential for social and economic disruptions that may occur within local and regional economies as coal resources are exhausted.

Coal availability and recoverability studies have been completed on many areas in most of the major coal basins of the United States. One of those areas, the Hilight Quadrangle (7 ½ minute) within the Powder River Basin (Molina, and others, 1999), will be used to demonstrate the relationship between the USGS studies and the U. N. Framework Classification. The many steps in calculating available/recoverable resources and reserves are summarized in figure 5.

As a result of these calculations, it was determined that only 11 percent (0.4 thousand million tons) of the original 3.3 thousand million tons of Wyodak-Anderson coal in this 150 square kilometre area (Hilight Quadrangle) was economically recoverable under existing economic

conditions(USGS, 1999). The original resource, recoverable resource, and the economically recoverable resource as calculated in the USGS analyses are plotted on the UNFC chart (fig. 6) and fall into the following fields as designated by the UNFC codes: original resource, 331, 332, and 333; recoverable resource, 221 and 222; and economically recoverable resource, 121 and 122. Although 11 percent might appear to be a low value for economically recoverable coal, it is very similar to results of other availability/recoverability analyses for coals from basins in both the eastern and western parts of the United States (M.D. Carter, USGS, personal communication).

CONCLUSIONS

Coal resource analyses at the U.S. Geological Survey are local, regional and national in scope. Generally, it is the resource (intrinsic economic value) that is determined, and the values reported are readily classified as geological studies on the Feasibility Axis of the United Nations Framework Classification. Recently, because of advances in GIS methods, and heightened interest in economic analyses, studies referred to as “coal availability” and “coal recoverability” have been completed. These involve much more detailed analyses and include calculating costs of coal production (coal supply). Resource values from these studies are placed in the boxes of prefeasibility studies along the Feasibility Axis. There is little to no ambiguity in relating the US national system, based on the McKelvey box, to the United Nations Framework Classification and this observation is valid for studies of local, regional or national scope.

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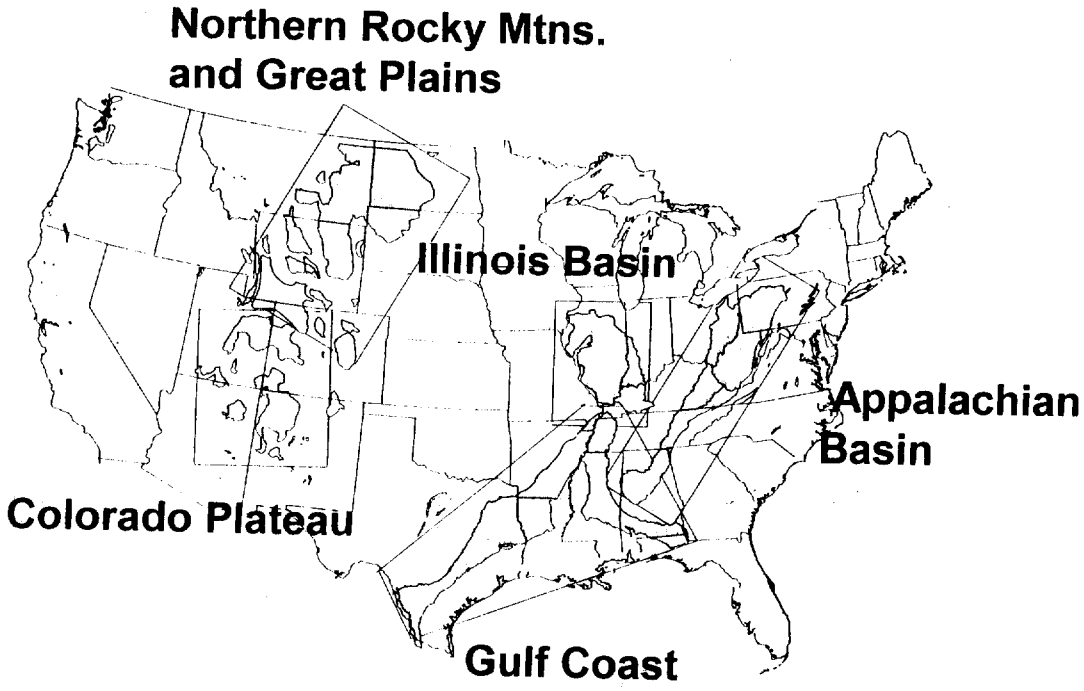

Figure 1. National Coal Resource Assessment Regions

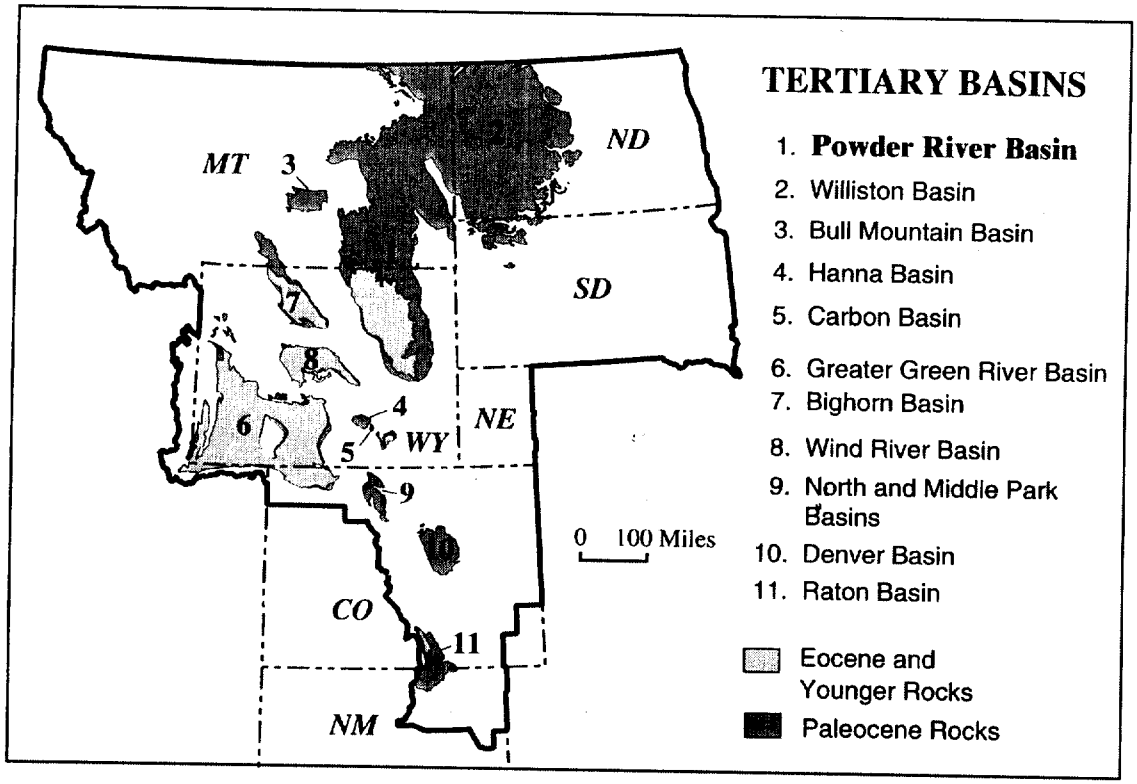

Figure 2. Northern Rocky Mountain and Northern Great Plains, showing location of the Powder River Basin.

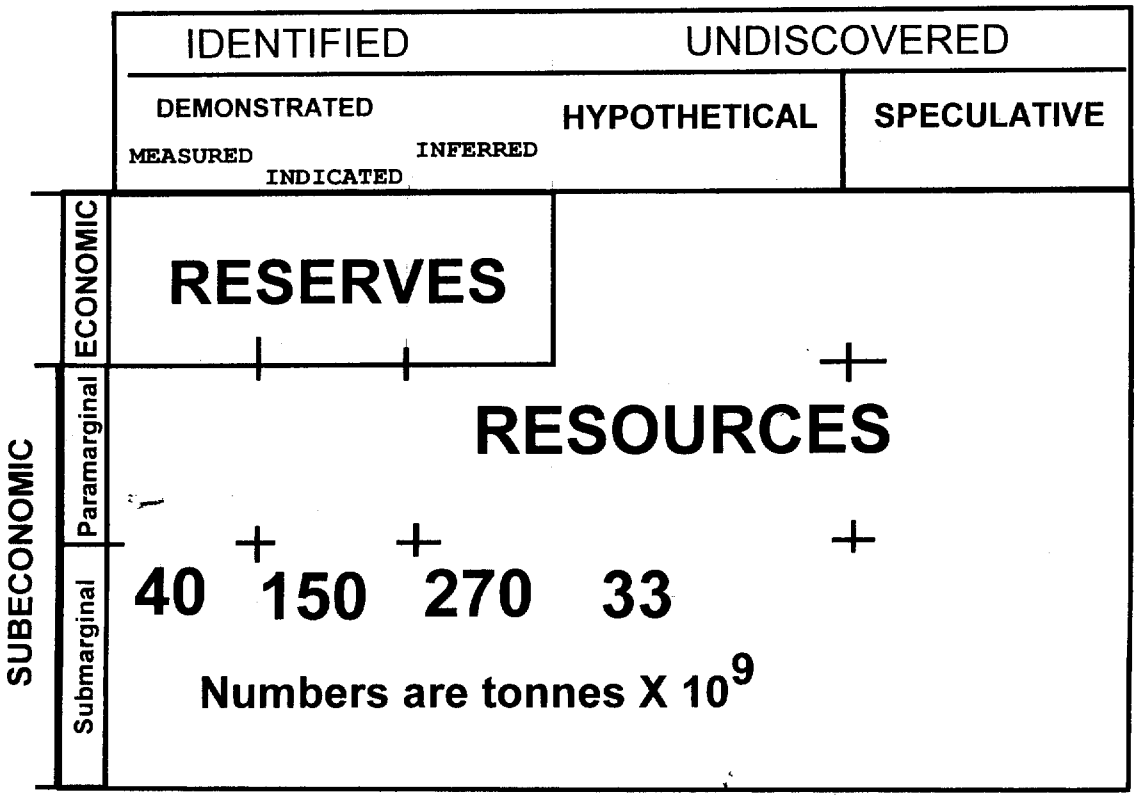

Figure 3. Wyodak-Anderson coal resources shown on the "McKelvey Box", the standard for reporting resources and reserves at the U.S., Geological Survey (after Wood and others, 1983)

UNFC	Detailed Exploration	General Exploration	Prospecting	Reconnais-sance
Feasibility	111 211			
Pre-Feasibility	121 221	122 222		
Geological	**40**	**150**	**270**	**33**

Figure 4. Wyodak-Anderson coal resources related to United Nations Framework Classification (UNFC). Large, bold numbers are tonnes times ten to the ninth (thousand million). Small, three digit numbers (111, 211, etc) are codes defined in the UNFC.

COAL AVAILABILITY STUDIES

ORIGINAL COAL
- minus -
AREAS ALREADY MINED
- minus -
LAND-USE RESTRICTIONS
- minus -
TECHNOLOGIC CONSIDERATIONS
- equals -
COAL AVAILABLE FOR MINING

COAL RECOVERABILITY STUDIES

COAL AVAILABLE FOR MINING
- minus -
MINING LOSSES
- minus -
WASHING LOSSES
- equals -
RECOVERABLE RESOURCES
- minus -
MINABLE RESOURCES TOO COSTLY TO EXTRACT
- equals -
ECONOMICALLY RECOVERABLE RESOURCE (***RESERVE***)

Figure 5. Steps to calculate economically recoverable coal from original coal resource: a prefeasibility study.

UNFC	Detailed Exploration	General Exploration	Prospecting	Reconnais-sance
Feasibility	111 211			
Pre-Feasibility	0.4 (Reserve - 11%) 2.9(Resource - 89%)			
Geological	3.3			

Figure 6. Hilight Quadrangle Resources as a result of coal availability/coal recoverability (prefeasibility) analyses (Molnia, and others, in USGS, 1999). Large, bold numbers are tonnes times ten to the ninth.