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COAL EXPLORATION STAGE I, UATSI PROJECT, BAJA TALAMANCA, COSTA RICA RESULTS AND RECOMMENDATIONS

by

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EXECUTIVE SUMMARY

In 1983, a technical assistance project in coal exploration was initiated between the U.S. Geological Survey (USGS) and the Direccion de Recursos Carboniferos in Refinadora Costarricense de Petroleo, S. A. (RECOPE), under the guidance and sponsorship of the United States Agency for International Development (AID). The work plan under which the project was conducted had a prime objective of helping the RECOPE geoscientists and technicians to attain, through technology transfer by USGS personnel, experience and expertise in coal exploration and resource assessment so that they might realistically evaluate the coal resources of Costa Rica in terms of quantity, quality, and potential utilization.

A major part of the work conducted during the project was an Exploration Stage I study of the Uatsi project area in the southern part of the Baja Talamanca coal field. This phase of exploration included creation of information by drilling and bore-hole geophysical logging to allow correlation of coal beds of potential interest, estimation of resources to at least an assurance category of indicated (probable), and to obtain a preliminary understanding of the quality of the coal and its potential utilization. During this stage, 20 exploratory drill holes were completed, samples from drill cuttings and cores were collected and described, coal samples were selected for analysis, and geophysical logs were made and interpreted. A report on the results of the study, comprising 120 pages of text and 30 illustrations, was prepared by Kenneth Bolanos I., with the assistance of other RECOPE personnel. The report will provide guidance during subsequent exploration phases in both the Uatsi project area and adjoining parts of the Baja Talamanca coal field. This executive summary and overview is derived from the RECOPE report with the addition of comparative contributions by USGS personnel.

The potentially economic coal beds in the Uatsi project area are in the Middle Member of the Gatun Formation of Miocene Age. The formation in this area consists of: 1) a dominantly sandy Lower Member at least 270 m thick, 2) a Middle Member divided into a coaly lower part as much as 320 m thick, and a dominantly sandstone upper part as much as 600 m thick, and 3) a sandy and conglomeratic Upper Member as much as 450 m thick. The Gatun is underlain, probably conformably, by the Uscari Formation, a dominantly fine to very fine grained clastic rock sequence at least 750 m thick. The Suretka Formation of Pleistocene and or Pliocene Age, which unconformably overlies the Gatun in the Baja Talamanca coal field, ranges from 200 to 1,000 m thick, but has been eroded from the Uatsi project area.

Structurally, the area is complex. The coal-bearing rocks are folded and faulted; displacements range from small to large, and the net effect is division of the area into fault-bounded blocks. Correlation of the rock sequences and

coal beds between blocks is difficult. For coal resource purposes, the structurally-defined blocks are treated as individual entities.

Within the fault-bounded blocks, resources were estimated for four coal beds for which correlation within the individual blocks is reasonably assured. Other coal beds are present, but their correlation is uncertain with the present density of information, and no resources were estimated for the uncorrelated beds.

Two independent resource estimates have been made using the same basic information, but applying slightly different resource parameters and interpretations. Estimate I was made in July as part of the report prepared for RECOPE. Estimate II was made in August for this report for comparative purposes.

The estimates in millions of metric tons (t) are:

Assurance Category	Estimate I	Estimate II
Measured	8.704	9.687
Indicated	4.146	3.191
Inferred	4.210	0.164
Total	17.060	13.042

A comparison of the two estimates shows that the totals of the measured and indicated categories, which in USGS practice are combined as demonstrated category resources, are nearly the same, with 12.850 in Estimate I and 12.878 in Estimate II. The major difference in the estimates is in the inferred category, where Estimate II is obviously more conservative.

In summary, with the available data a minimum of almost 13 million t of coal are estimated to be present in an assurance category of demonstrated in an area of about 6 km^2. Additional exploration is required and can be expected to further define and increase the estimated resources, both by adding to our knowledge about the four coal beds represented in the estimates to date, and by allowing estimation of resources in beds not included in the foregoing estimates. Most of the estimated resources must be recovered by underground mining, but some part, undefined as yet, can be recovered by surface mining.

Coal sample analyses, 10 by RECOPE and 6 by USGS contractors, show a range in coal rank from lignite B to high volatile C bituminous. The modal value is subbituminous C followed by lignite A. Those coal beds for which resources were estimated ranged in rank from subbituminous C to high volatile C bituminous, and again, the modal value is subbituminous C. The coal does not appear to have any caking properties; the four samples for which equilibrium moisture (inherent moisture by ASTM definition) was determined have an average of 25 percent inherent moisture; the five samples for which ash fusion temperatures were determined had an average initial ash deformation temperature of 2250° F, an average ash softening temperature of 2350° F, and an average fluid temperature of 2420° F. Three Hardgrove Grindability Indexes that were determined ranged from 41 to 58. Average sulfur content on as-received basis of 13 samples was 1.7 percent, but the range was from 0.28 to 5.22 percent. Forms of sulfur were determined for five samples; pyritic sulfur was dominant in three samples, and organic sulfur in the other two. The ash content of 15 samples on an as-received basis averaged 13.8 percent, and ranged from 6.3 to 35.6 percent.

Obviously, many more analyses of representative samples are needed for adequate characterizaton of the coals of the Uatsi project area, but at this time it appears that the coal is most likely to be of subbituminous C rank with medium sulfur and ash contents. This characterization should be used with caution because of the small number of samples analyzed to date.

Further exploration efforts should be designed to yield needed additional information in parts of the field already partially explored (Uatsi project area) and to begin the exploration needed for assessment of the coal resources of the remainder of the Baja Talamanca coal field. Exploration Stage II activities are underway in the Uatsi project area to provide data needed for mine planning and evaluation of utilization potential. Some of the Exploration Stage II activites will also provide information about areas outside the Uatsi project area.

INTRODUCTION

The technical assistance program in coal exploration that has been conducted in Costa Rica under the auspices of AID has the primary objective of helping a counterpart group of Costa Rican geoscientists attain experience and expertise in coal exploration and resource assessment so that the coal resources of the country can be realistically evaluated in terms of quantity, quality, and potential utilization.

Preliminary work leading to the technical assistance program began in 1981, and resulted in a summary by the USGS of the available coal information and the formulation of a program which has essentially formed the basis for subsequent exploration activities.

A total of nine different areas in Costa Rica had been reported to contain coal in 1981. Subsequently, more coal localities have been reported by citizens as a result of publicity about the coal exploration program in the national media. Of the original nine localities, all except one needed the Reconnaissance Exploration Stage study. The exception (Baja Talamanca) had received reconnaissance prior to 1981, and had even gone through an Early Exploration Stage study before USGS involvement in 1983.

Of the eight areas that required reconnaissance, six have been investigated and two remain to be looked at. Of the six areas studied, two exhibited sufficient resource potential to be eligible for more detailed investigation which they are now receiving. Two additional areas were reported by citizens recently, and one of these is presently undergoing the Reconnaissanace Exploration Stage study.

Part of the best known area, Baja Talamanca, has progressed through an Exploration Stage I phase which featured coal exploratory drilling and geophysical well logging. Twenty exploratory drill holes were successfully completed, core samples needed for quality determinations were obtained, natural radioactivity, density, resistivity, and caliper logs of the drill holes were made, and a basic understanding of the stratigraphic and structural framework of the coal-bearing rocks of the project area has been attained. The coal resources contained in four coal beds of primary interest were estimated in two separate exercises using slightly different parameters and interpretations of the same basic data set. A large comprehensive report on the Exploration Stage I, totaling about 120 pages plus about 30 illustrations at large scales was prepared by Kenneth

Bolanos I. and coworkers for the Direccion de Recursos Carboniferos of the Gerencia de Exploracion of Refinadora Costarricense de Petroleo, S. A. (RECOPE). The report will form the basis for all subsequent activities that will be conducted by RECOPE in the southern part of the Baja Talamanca coal field of Costa Rica. This overview is derived from the RECOPE report and includes contributions intended to supplement and strengthen the basic conclusions of the RECOPE report. The USGS personnel who assisted in the study were R. N. Babcock, R. G. Hobbs, E. R. Landis, R. L. Miller, S. B. Roberts, F. O. Simon, W. L. Smith, and J. N. Weaver.

The personnel of RECOPE who have conducted the Exploration Stage I program deserve hearty congratulations on their success. In less than 2 years, they planned, conducted, and completed a coal exploratory drill program that to the author's knowledge is the first and only modern detailed coal exploration activity of its type that has ever been conducted in Central America.

GEOLOGY

The Uatsi project area of the Baja Talamanca coal field is located in the southeastern part of the Province of Limon north of the Rio Sixaola that here forms the boundary between Costa Rica and Panama (fig. 1).

Figure 2 is a geologic map of the Uatsi project area with the locations of completed drill holes of the Exploration Stage I program, and locations of drill holes needed in the next stage of exploration.

The low-lying river and stream valleys in the area are underlain by the Uscari Formation of Oligocene and Miocene age. The Uscari is mainly a clay-sized clastic sequence that was deposited in marine environments. Carbonate-cemented units are present in the sequence, and the upper part is silty and sandy. The upper contact with the overlying Gatun Formation has been variously described as an unconformity, and as a conformable, gradational, transitional contact. The net effect in most places is to make selection of the Uscari-Gatun contact difficult. The Uscari is at least 750 m thick in the Baja Talamanca coal field.

The Gatun Formation of Miocene Age is dominantly composed of erosion-resistant coarser clastics ranging from siltstone to pebble and cobble conglomerate. As a result, topographically higher areas are commonly underlain by the resistant Gatun, and to some extent, the topography may reflect the geologic structure of an area. The Gatun in the Uatsi project area is divided into three members (fig. 3). The Lower Member of the Gatun was mostly deposited in relatively shallow water marine and marginal marine environments, and is composed predominantly of silt to medium-grained sand, though pebble-sized material is present in some parts. Marine fossils are common throughout the unit. The Lower Member is at least 270 m thick in the Uatsi project area.

The Middle Member is divided into the coaly lower part that was deposited in transitional marine, paralic and fluviatile environments, and an upper sandy part that was variously deposited in fluviatile, marginal marine, or marine environments. The potentially economic coal beds are in the lower part of the Middle Member. The coaly lower part of the Middle Member is as much as 320 m thick in parts of the Uatsi project area; the upper part of the Middle Member is as much as 600 m thick.

Figure 1. Index map showing known coal deposits in Costa Rica.

(p. 7 follows)

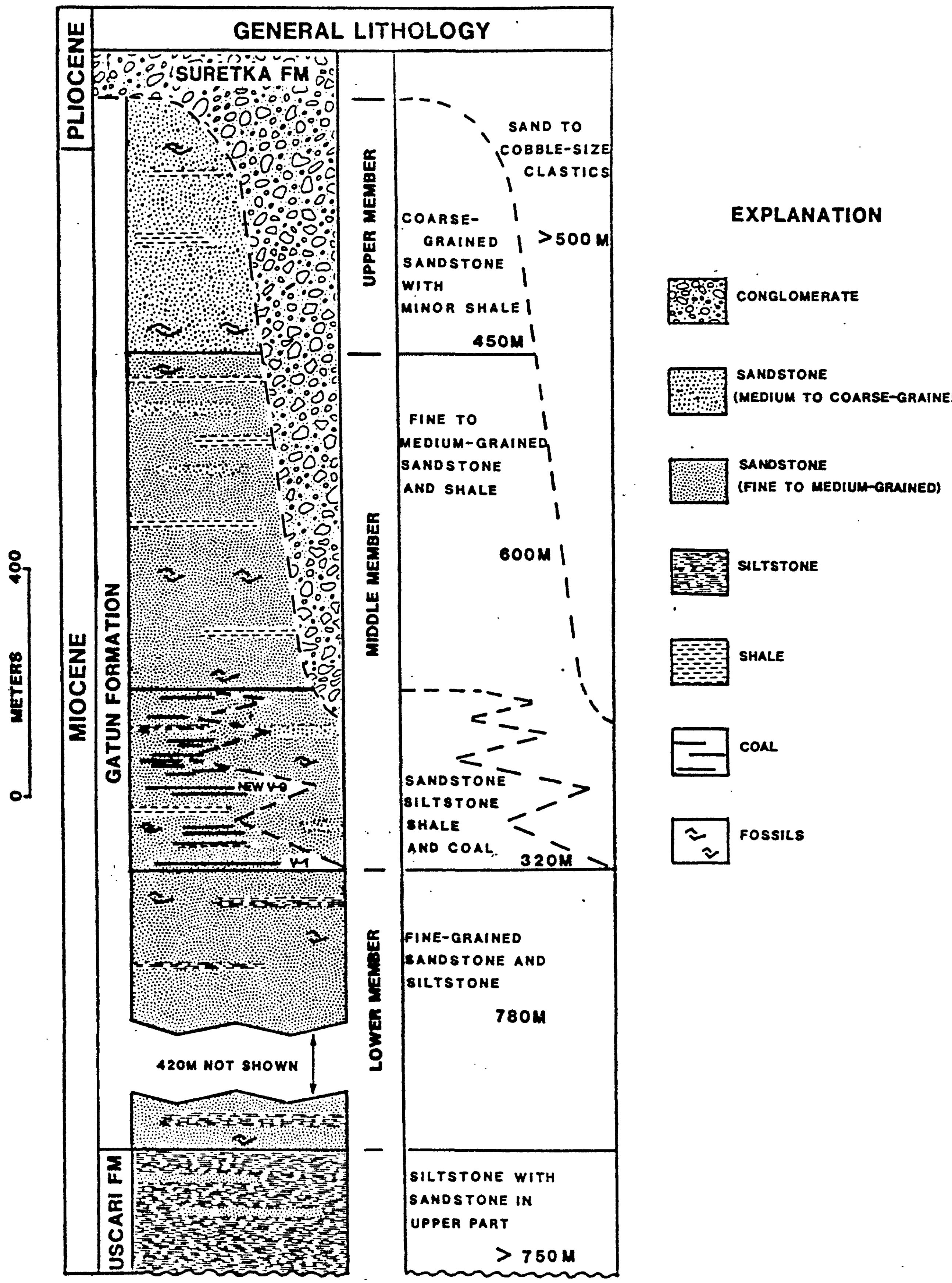


Figure 3. Generalized lithologic column for the Baja Talamanca coal field. The maximum thickness for individual units is shown in the right-hand column. These values do not necessarily represent the thicknesses of units in the Uatsi project area. Modified from Malavassi, 1985 (unpublished data).

The Upper Member of the Gatun Formation is generally sandstone that is coarser-grained than in the Middle Member, and contains pebbles and small cobbles in places; it is commonly more resistant than the two lower members of the Gatun. With the exception of recent alluvium along streams and colluvium on the hill slopes, the Upper Member is the youngest rock unit identified in the Uatsi project area. The Upper Member is as thick as 450 m in the Uatsi project area.

In other parts of the Baja Talamanca coal field, the Gatun Formation is overlain by the Suretka Formation of Pleistocene and/or Pliocene age. The contact is erosional, and appears to be of high relief. The Suretka is composed mostly of sand to cobble-sized clastics shed off the source areas to the west. The Suretka has not been mapped in the Uatsi project area, but colluvial material derived from it by erosion is common almost everywhere. The Suretka ranges in thickness from 200 to 1,000 m in the Baja Talamanca area.

The area is complex structurally with both anticlines and synclines strongly modified by later faulting. Many of the faults are high angle reverse with the upthrown side generally on the west. Relative displacement ranges from hundreds of meters to only a few meters.

ESTIMATION OF RESOURCES

Comparison of total resource estimates

For coal resource assessment, the Uatsi project area can be conveniently divided into subareas bounded by faults and geologic contacts. Correlation of coal beds between subareas is very difficult; correlations within some subareas can be made with reasonable assurance, but not in others where adequate data are lacking. Two separate estimates have been made for resources in coal beds of three subareas: East Rio Carbon Volio, West Rio Carbon Volio, and North Rio Carbon Volio (table 1 and index map on fig. 2). Coal resources have not been estimated in other subareas because of inadequate data. The first estimate was made in July for the RECOPE comprehensive report. The second estimate was made in August for this report. Both estimates used the same basic information, but were made using slightly different parameters and data interpretations. The first estimate was completely independent; the second had the benefit of the first, plus freedom to change resource parameters and interpretation of data.

Table 1 is a summary of the estimates arranged for comparison. In Estimate I, measured resources are all within 0.25 km of a point of information, indicated resources are between 0.25 to 0.5 km from an information point, and inferred resources are beyond 0.5 km. In Estimate II, measured resources are within 0.4 km of an information point, indicated resources are between 0.4 to 1.2 km from an information point, and inferred resources are beyond 1.2 km of an information point. The closeness of the estimates is shown by the fact that the totals of measured and indicated resources are essentially the same--12.850 and 12.878, respectively. These combined categories are defined as the demonstrated resource category by USGS practice. Comparison of the two estimates shows that they validate each other despite differences in parameters and interpretation philosophy.

Table 1. Summary of resource estimates in millions of metric tons. (upper left number is Estimate I RECOPE, July 1985; lower right number is Estimate II - USGS, August 1985)

Area	Coal bed	Assurance Category			Total
		Measured	Indicated	Inferred	
Subarea East Rio Carbon Volio	V-7	1.917 / *2.027*	1.210 / ---	--- / ---	3.127 / *2.027*
Subarea West Rio Carbon Volio	V-1	1.814 / *2.490*	1.149 / *1.055*	2.162 / *0.051*	5.125 / *3.596*
	New V-9	2.924 / *2.718*	1.214 / *2.136*	2.048 / *0.113*	6.186 / *4.967*
Subarea North Rio Carbon Volio	V-9	2.049 / *2.452*	0.573 / ---	--- / ---	2.622 / *2.452*
Uatsi Project		8.704 / *9.687*	4.146 / *3.191*	4.210 / *0.164*	17.060 / *13.042*

Both estimates present resources by subarea, coal bed, and three assurance categories; however, Estimate II was calculated also using three coal bed thickness categories, three overburden thickness categories, and an area of estimate for each grouping.

Comparison of estimated resources by subarea

In the subarea East Rio Carbon Volio, resources were estimated for the V-7 coal bed (fig. 3, table 1 and table 2). As shown in figure 3, a small part of the estimated measured resources might be recoverable by surface mining along the outcrop. The bulk of the resources would have to be recovered by underground mining. About 75 percent of the estimated resources are in the 75 to 150 cm thickness category (2 1/2 to 5 feet), and all estimated resources are in the measured assurance category according to Estimate II (table 2), and most are in the measured category, according to Estimate I (table 1).

In the subarea West Rio Carbon Volio, resources were estimated for two coal beds (table 1)--the V-1 bed (fig. 4) near the base of the coaly lower part of the Middle Member of the Gatun Formation, and the New V-9 bed (fig. 5) near the top of the lower part of the Middle Member. Estimate 1 (table 1) totals more than five million t for the V-1 bed, and more than six million t for the New V-9 bed. Estimate II (tables 3 and 4) totals about 3.6 million t for the V-1 bed, and about 5 million t for the New V-9 bed. Total estimated resources for the two beds differ by almost three million t (table 1). The bulk of this difference is in the inferred assurance category. In the combined measured and indicated category--the demonstrated category--Estimate II totals more than 1.2 million t larger than Estimate I. Table 3 shows that about two-thirds of the resources estimated for the V-1 bed are at overburden depths of more than 150 m, and would have to be recovered by underground mining. Some coal, however, might be recovered by surface mining along the outcrop. In contrast to the V-1 bed, almost 45 percent of the estimated resources of the New V-9 bed are overlain by less than 90 m of overburden (table 4), and a considerable part might be recoverable by surface mining, depending on the relative ratio of coal thickness to overburden thickness (or weight, or volume) that would be acceptable. The average thickness of the New V-9 bed in the 2.61 km^2 area in which resources were estimated (table 4) is about 1.5 m.

In the subarea North Rio Carbon Volio (fig. 6), resources were estimated for the V-9 coal bed. The V-9 of this subarea and the New V-9 bed of the subarea West Rio Carbon Volio are confidently believed to be the same bed, but are areally separated by the faults that bound the different subareas. By virtue of the distribution of data points, and the relatively small size of the subarea, the total resource estimates for the V-9 bed are essentially the same for Estimate I and Estimate II. Despite the fact that more than 45 percent of the estimated resources of the V-9 bed are at depths of less than 90 m (table 5), most of the bed would probably have to be recovered by underground mining. The average thickness of the V-9 bed in the subarea North Rio Carbon Volio is about 1.6 m.

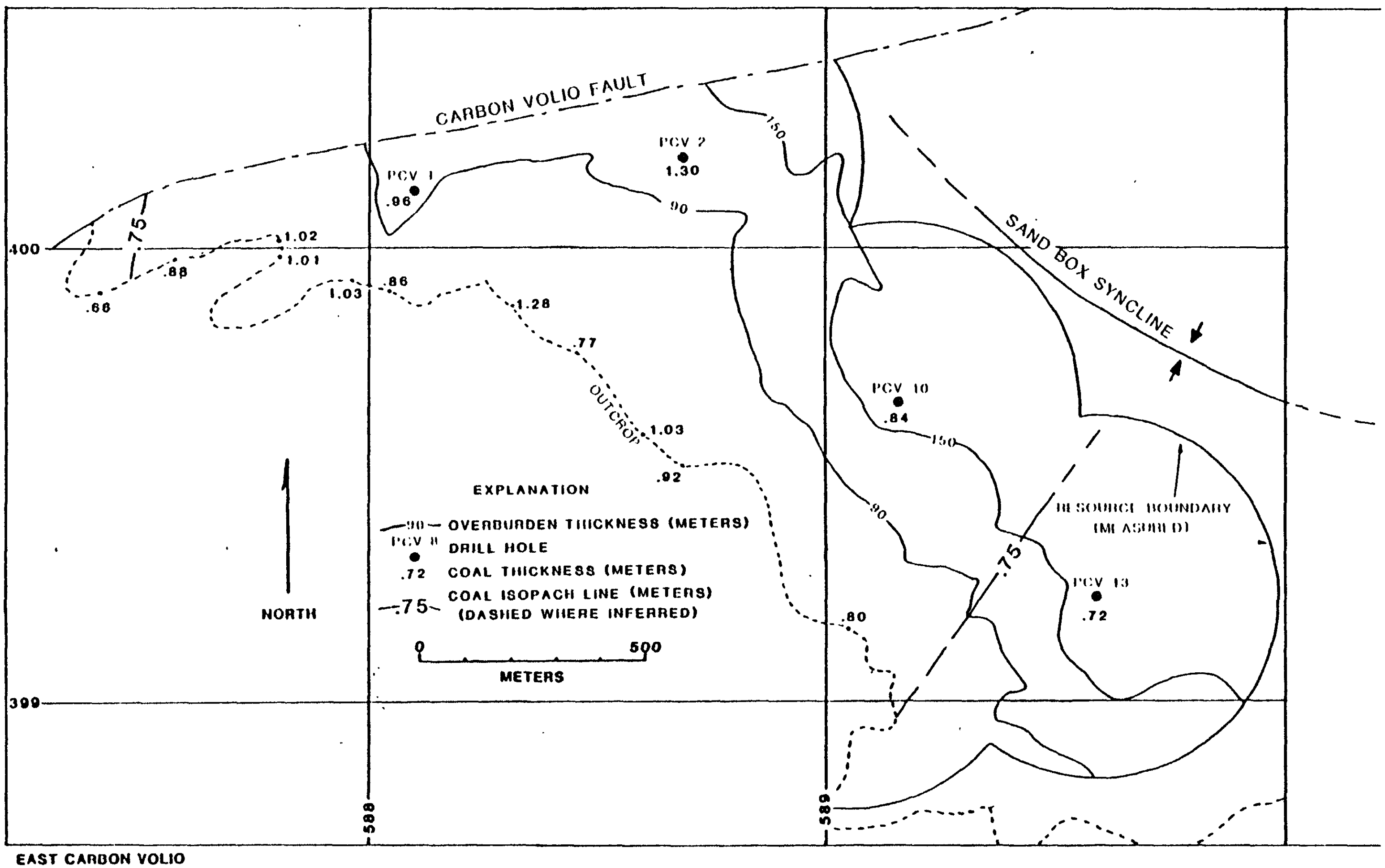


Figure 4: Area of resource calculation on V-7 coal bed.

Table 2. Estimated Resources, V-7 coal bed, subarea East Rio Carbon Volio (USGS, August 1985)

		V-7 Coal Bed									
USGS assurance category	Overburden	0 to 90 meters			90 to 150 meters			> 150 meters			Total
	Coal bed thickness	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	
Measured	Metric tons ($x10^3$)	118.5	747.1		109.0	452.4		231.4	368.1		2,026.5
	Area (km^2)	0.13	0.59		0.11	0.36		0.24	0.29		1.72
Indicated	Metric tons ($x10^3$)										
	Area (km^2)										
Inferred	Metric tons ($x10^3$)										
	Area (km^2)										
Total	Metric tons ($x10^3$)	118.5	747.1		109.0	452.4		231.4	368.1		2,026.5
	Area (km^2)	0.13	0.59		0.11	0.36		0.24	0.29		1.72
Total by overburden category	Metric tons ($x10^3$)		865.6			561.4			599.5		
	Area (km^2)		0.72			0.47			0.53		

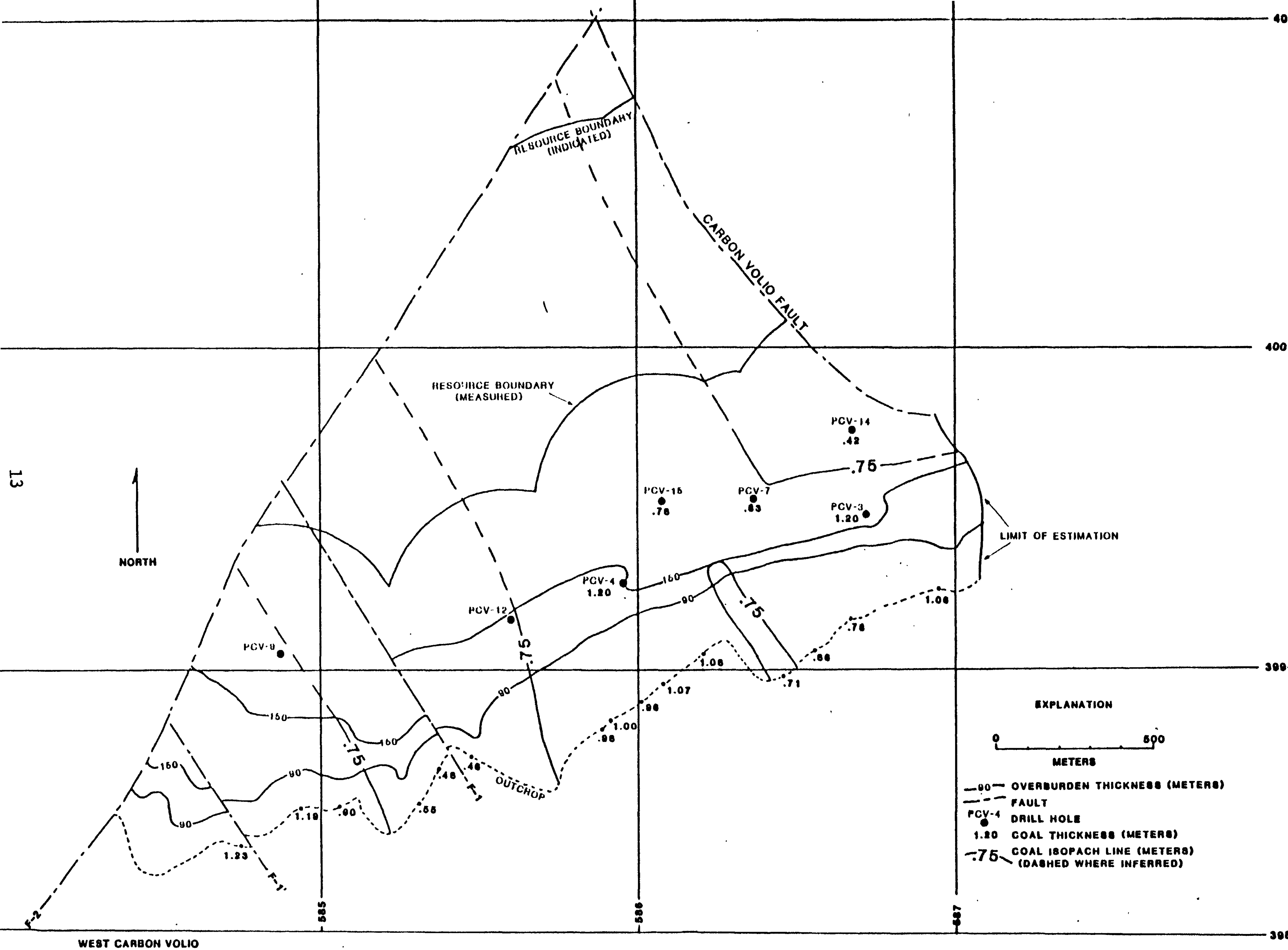
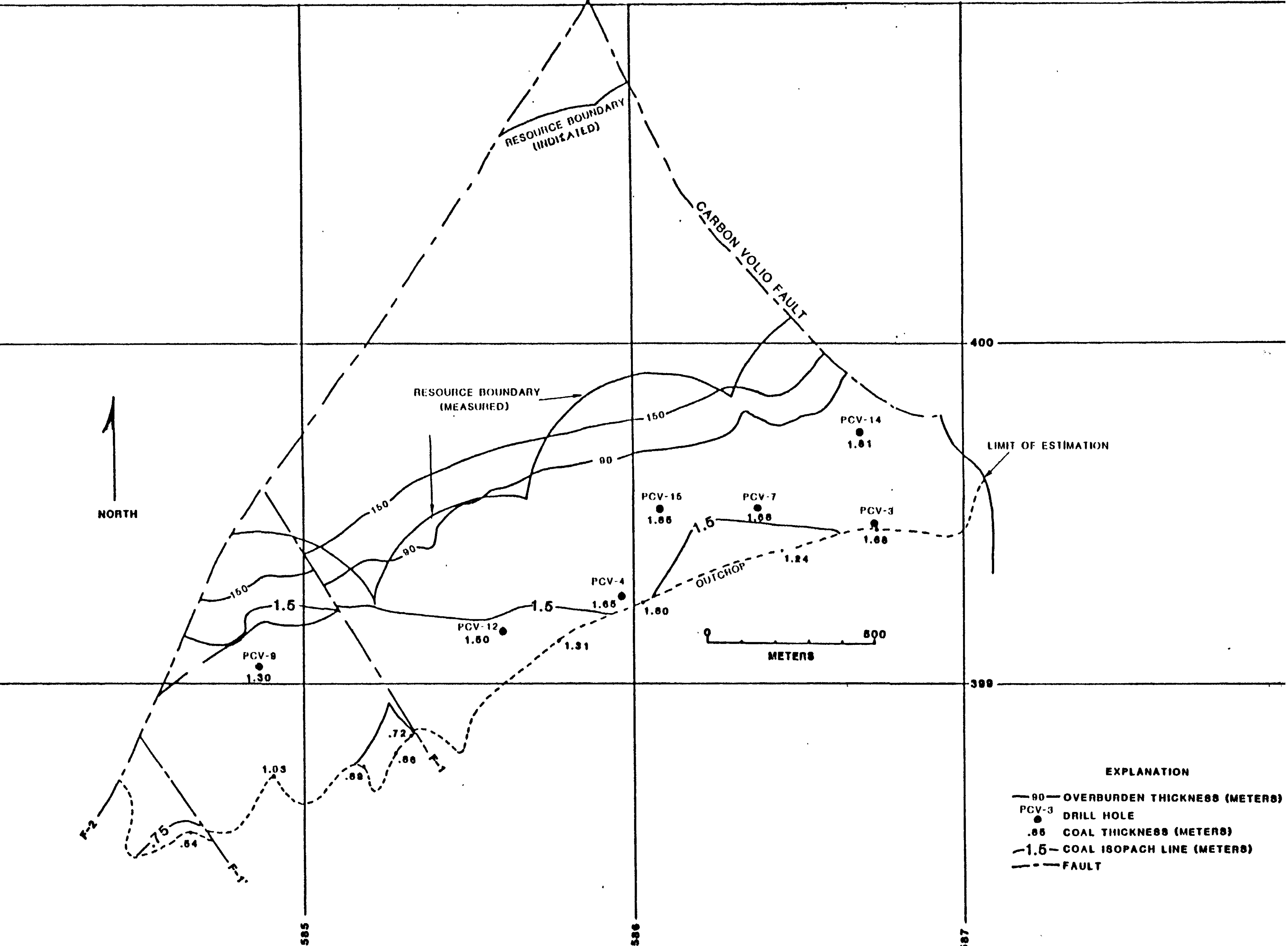


Figure 5: Area of resource calculation on V-1 coal bed.



WEST CARBON VOLIO

Figure 6: Area of resource calculation on new V-9 coal bed.

Table 3. Estimated Resources, V-1 coal bed, subarea West Rio Carbon Volio (USGS, August 1985)

		V-1 Coal Bed									
USGS assurance category	Overburden	0 to 90 meters			90 to 150 meters			> 150 meters			Total
	Coal bed thickness	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	
Measured	Metric tons ($x10^3$)	103.6	605.7		94.7	470.2		424.2	791.1		2,489.5
	Area (km^2)	0.13	0.43		0.12	0.33		0.53	0.63		2.17
Indicated	Metric tons ($x10^3$)							336.1	718.9		1,055.0
	Area (km^2)							0.42	0.60		1.02
Inferred	Metric tons ($x10^3$)							35.1	16.2		51.3
	Area (km^2)							0.04	0.01		0.05
Total	Metric tons ($x10^3$)	103.6	605.7		94.7	470.2		795.4	1526.2		3,595.8
	Area (km^2)	0.13	0.43		0.12	0.33		0.99	1.24		3.24
Total by overburden category	Metric tons ($x10^3$)		709.3			564.9			2321.6		
	Area (km^2)		0.56			0.45			2.23		

Table 4. Estimated Resources, New V-9 coal bed, subarea West Rio Carbon Volio (USGS, August 1985)

	New V-9 Coal Bed										
USGS assurance category	Overburden	0 to 90 meters			90 to 150 meters			> 150 meters			Total
	Coal bed thickness	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	
Measured	Metric tons ($x10^3$)	6.3	861.4	1316.5		40.0	333.0			160.8	2,718.0
	Area (km^2)	0.01	0.56	0.63		0.03	0.16			0.08	1.47
Indicated	Metric tons ($x10^3$)		26.4	22.4			166.9			1920.2	2,135.9
	Area (km^2)		0.02	0.01			0.08			0.97	1.08
Inferred	Metric tons ($x10^3$)									112.8	112.8
	Area (km^2)									0.06	0.06
Total	Metric tons ($x10^3$)	6.3	887.8	1338.9		40.0	499.9			2193.8	4,966.7
	Area (km^2)	0.01	0.58	0.64		0.03	0.24			1.11	2.61
Total by	Metric tons ($x10^3$)		2233.0			539.9			2193.8		
overburden category	Area (km^2)		1.23			0.27			1.11		

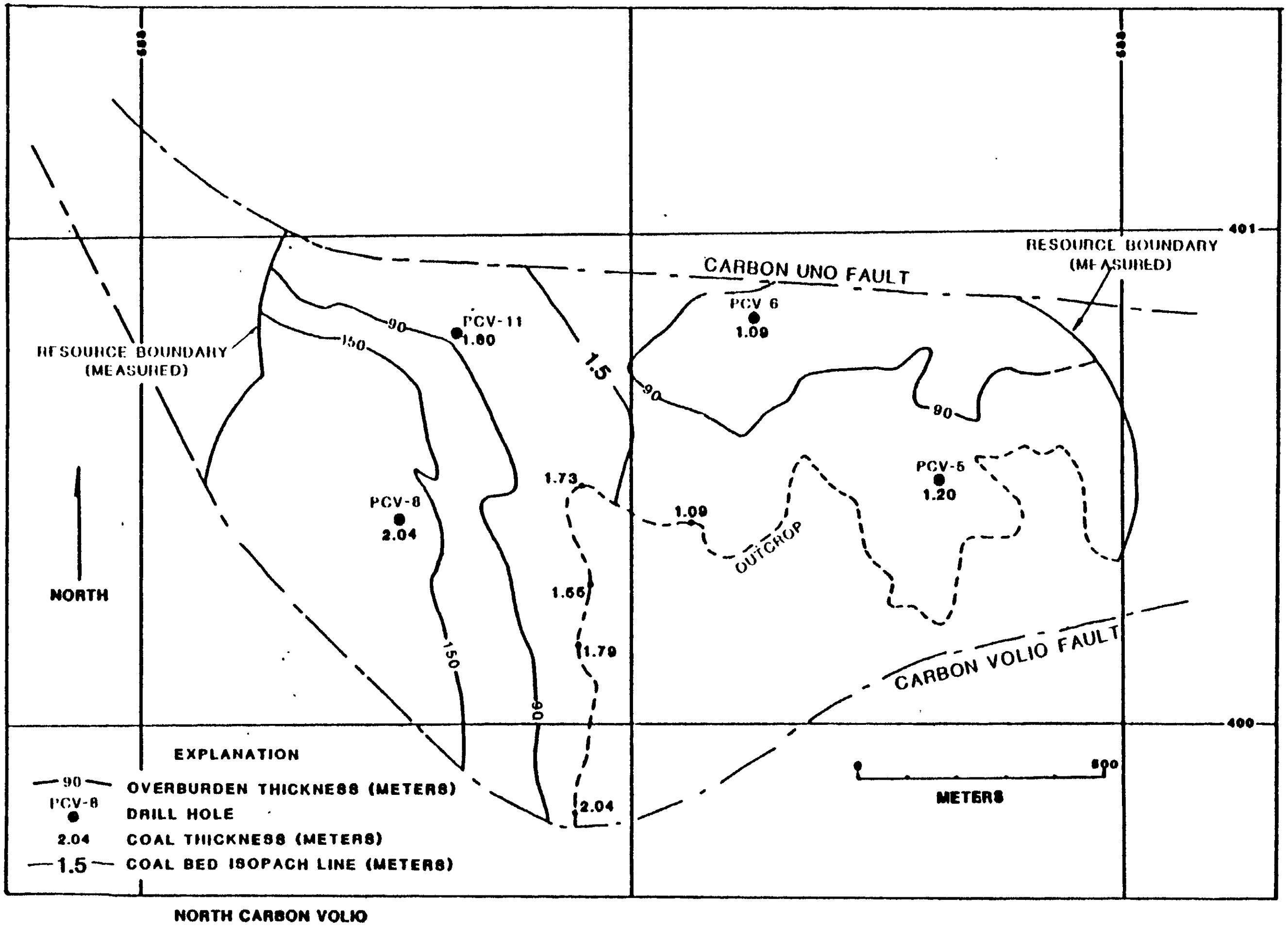


Figure 7: Area of resource calculation on V-9 coal bed.

Table 5. Estimated Resources, V-9 coal bed, subarea North Rio Carbon Volio (USGS, August 1985)

		V-9 Coal Bed									
USGS assurance category	Overburden	0 to 90 meters			90 to 150 meters			> 150 meters			Total
	Coal bed thickness	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	0 to 75 cm	75 to 150 cm	> 150 cm	
Measured	Metric tons ($x10^3$)		524.2	606.3		273.7	398.5			649.4	2,452.1
	Area (km^2)		0.34	0.24		0.18	0.16			0.26	1.18
Indicated	Metric tons ($x10^3$)										
	Area (km^2)										
Inferred	Metric tons ($x10^3$)										
	Area (km^2)										
Total	Metric tons ($x10^3$)		524.2	606.3		273.7	398.5			649.4	2,452.1
	Area (km^2)		0.34	0.24		0.18	0.16			0.26	1.18
Total by overburden category	Metric tons ($x10^3$)		1130.5			672.2			649.4		
	Area (km^2)		0.58			0.34			0.26		

COAL QUALITY

Table 6 presents analyses of 16 samples of coals from the Uatsi project area of the Baja Talamanca coal field. All except one are core samples from the exploratory drill holes.

Coals are commonly classified in three manners--by rank, type, and grade. Rank is classification according to position in the metamorphic series that begins with peat and ends with graphite. Rank in the American Society for Testing and Materials (ASTM) system is based on heat value in lower-rank coals and on fixed carbon and volatile matter contents in higher-rank coals. Tests for agglomerating properties are specified in part of the classification series. Proper rank classification is essential in coals because of the direct relationship between rank and prediction of a wide range of properties and of potential utilization possibilities. Apparent rank was determined for 13 of the analyzed samples. The rank ranged from lignite B to high volatile C bituminous. The modal rank designation is subbituminous C.

Determination of moisture content is of vital importance in lower rank coals because of the direct relationship between the moisture content and other properties. The total moisture content is considered to be composed of surface moisture and inherent moisture. Surface, or free, moisture is loosely attached to the coal particles. Inherent, or bed, moisture is largely between the coal particles, and is more firmly attached. Moisture content of samples can be modified by a great variety of events and conditions that add or remove moisture. The equilibrium (or bed or inherent) moisture is that which exists as a quality of the coal bed as it exists in its natural state of deposition, and includes only that water considered to be part of the deposit and not that moisture which exists as a surface addition. Equilibrium moisture was determined for four of the Uatsi project samples according to the method standardized by the ASTM. Ranks determined using the analyses modified to equilibrium moisture are shown in table 6 In all cases, the "equilibrium moisture ranks" are the same or a higher than the ranks calculated from the as-received analyses, and again, the modal rank designation is subbituminous C.

Classification of coals by type is dependent on petrographic determination of the organic constituents, and some inorganic constituents, of the coal. The relative content and distribution of the constituents can be of great importance in predicting the behavior of the coal during combustion or conversion processes. At this time, type classification of the Uatsi project samples is not possible because of lack of petrographic study.

Grade classfication is usually based on the content of deleterious materials in the coal. Generally, ash and sulfur contents are used for grade classification, but in low-rank-coals moisture may be considered deleterious, especially in technology such as coal-water-mix fuels. Though not usually classed as a deleterious constituent, the volatile matter content may be of great importance in some coal usages. The percent ash content of the samples listed in table 6 on an as-received basis ranges from 6.3 (low) to 35.6 (high), and averages 13.8 (medium) with a standard deviation of 7.9. The percent sulfur content on the same basis ranges from 0.28 (low) to 5.22 (high) and averages 1.7 (medium) with a standard deviation of 1.34.

Table 6.--Analyses of samples. L-prefix samples by RECOPE, remainder by USGS contractors

[Condition (1) as-received; (2) dry; (3) dry, ash-free; (4) changed to equilibrium moisture]

Sample Number Laboratory- Field-		Proximate Analysis				Ultimate Analysis					Heating Value Btu/lb	Forms of Sulfur			Equilibrim Moisture	Free Swelling Index	Hardgrove Grindability	Ash Fusion Temperatures (°F)			Apparent Specific Gravity	Apparent Rank	
		Moisture	Ash	Volatile Matter	Fixed Carbon	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen		Sulfate	Pyritic	Organic				Initial Deformation	Softening Temperature	Fluid Temperature			
L03310185	(1)	24.0	8.1	---	---	---	---	---	---	---	9,041												New V-9 bed
PCV-14-M-2	(2)	---	10.1	---	---	---	---	---	---	---	11,210												1.6 m thick, 50 m depth
	(3)	---	---	---	---	---	---	---	---	---	12,388												
L04180285	(1)	27.9	7.6	11.9	52.6	---	---	---	0.28	---	10,732											hv Cb	New V-9 bed
PCV-12-M-1	(2)		10.5	16.5	79.9	---	---	---	0.39	---	14,884												0.45 m thick, 33 m depth
	(3)			14.9	66.0	---	---	---	0.35	---	16,637												
L19070575	(1)	14.8	6.3	38.1	40.8	---	---	---	0.81	---	8,892											sub B	New V-9 bed
PCV-7-M-1(A)	(2)		7.6	45.7	46.7	---	---	---	0.97	---	10,661												0.30m thick, 20.7 m depth
	(3)			57.9	42.1	---	---	---	1.02	---	11,270												
L16290485	(1)	24.4	19.3	34.5	21.8	---	---	---	0.40	---	9,290											hv Cb	New V-9 bed
PCV-7-M-1(B)	(2)		25.6	45.6	28.8	---	---	---	0.50	---	12,289												0.92 m thick, 21 m depth
	(3)			61.3	38.7	---	---	---	0.70	---	16,501												
L12290485	(1)	25.6	9.7	42.1	22.6	---	---	---	0.60	---	8,577											sub B	New V-9 bed
PCV-7-M-1(C)	(2)		13.0	56.6	30.4	---	---	---	0.84	---	11,529												0.40 m thick, 27 m depth
	(3)			65.1	34.9	---	---	---	0.97	---	13,255												
L18070585	(1)	12.2	57.2																				New V-9 bed
PCV-7-M-1(D)	(2)																						Not coal, 0.45 m thick,
	(3)																						27.4 m depth
L01310185	(1)	23.6	11.5	24.7	40.2	---	---	--	---	---	7,772												V-1 bed
PCV-7-M-2	(2)		---	---	---	---	---	---	---	---	9,637												0.61 m thick, 167 m depth
	(3)			---	---	----	---	---	---	---	11,192												
L21070585	(1)	18.1	7.7	38.8	35.4	---	---	---	0.77	---	8,698											sub C	V-9 bed
PCV-11-M-2(A)	(2)		9.4	47.4	43.2	---	---	---	0.94	---	10,620												0.285 m thick, 79.3 . depth
	(3)			63.9	36.1	---	---	---	1.04	---	11,722												
L22070585	(1)	15.2	9.9	41.5	33.4	---	---	---	2.06	---	7,466											sub C	V-9 bed
PCV-11-M-2(B)	(2)		11.7	48.9	39.4	---	---	---	2.43	---	8,806												0.49 m thick, 79.6 m depth
	(3)			65.3	34.7	---	---	---	2.75	---	9,968												

Table 6.--Analyses of samples. L-prefix samples by RECOPE, remainder by USGS contractors--cont.

Sample Number Laboratory- Field-		Proximate Analysis				Ultimate Analysis					Heating Value Btu/lb	Forms of Sulfur			Equilibrium Moisture	Free Swelling Index	Hardgrove Grindability	Ash Fusion Temperatures (°F)			Apparent Specific Gravity	Apparent Rank	
		Moisture	Ash	Volatile Matter	Fixed Carbon	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen		Sulfate	Pyritic	Organic				Initial Deformation	Softening Temperature	Fluid Temperature			
W226187	(1)	40.03	22.47	21.14	16.36	6.72	26.09	0.52	2.47	41.73	4,622	0.00	1.45	1.02	23.58	0.0	---	2,210	2,340	2,480		lig B	U-6 bed
PCU-1-M-3	(2)		37.46	35.26	27.28	3.74	43.51	0.88	4.12	10.29	7,708	0.00	2.41	1.71									0.92 m thick, 130 m depth
	(3)			56.38	43.62	5.98	69.58	1.41	6.59	16.44	12,326	0.00	3.85	2.74									
	(4)	23.58	28.63	26.94	20.85	5.49	33.25	0.66	3.15	28.82	5,890	0.00	1.85	1.3								sub C	
L10220485	(1)	30.1	11.0	10.1	48.8	---	---	---	2.24	---	7,321											lig A	U-6 bed
PCU-3-M-1	(2)		15.8	14.4	69.8	---	---	---	3.20	---	10,472												0.60 m thick, 40 m depth
	(3)			17.1	82.9				3.80	---	12,429												
W227096	(1)	25.55	35.63	22.99	15.83	5.21	23.77	0.38	5.22	29.79	4,160	0.12	3.30	1.80	24.07	0.0	58	2,300	2,420	2,480		lig B	U-3 bed
PCU-1-M-7	(2)		47.85	30.88	21.27	3.16	31.93	0.50	7.02	9.54	5,587	0.17	4.43	2.42									0.55 m thick
	(3)			59.22	40.78	6.06	61.23	0.96	13.46	18.29	10,717	0.33	8.50	4.63									
	(4)	24.07	36.34	23.45	16.15	5.09	24.24	0.39	5.32	28.62	4,240	0.12	3.37	1.84								lig A	
W227097	(1)	26.00	21.50	28.90	23.60	6.17	37.95	0.70	1.48	32.20	6,610	0.01	0.89	0.58	26.92	0.0	46	2,370	2,450	2,470		sub C	V-7 bed
PCV-1-M-1	(2)		29.05	39.05	31.90	4.41	51.29	0.95	2.00	12.30	8,933	0.01	1.20	0.79									
	(3)			55.04	44.96	6.22	72.29	1.34	2.82	17.33	12,591	0.01	1.69	1.12									
	(4)	26.92	21.23	28.54	23.31	6.23	37.48	0.69	1.46	32.91	6,530	0.01	0.88	0.57								sub C	
	(1)	26.67	8.14	36.03	29.16	3.85	47.66	0.85	0.89	11.94	8,275	---	---	---	26.0	---	41	---	---	---	1.3	sub C	V-9 bed
L-5 (1981	(2)		11.10	49.13	39.77	5.25	65.00	1.16	1.22	16.27	11,285												Outcrop sample, 1.1 m thick
	(3)	---	---	---	---	---	---	---	---	---	---												Chlorine 0.00 %
	(4)	26.00	8.21	36.36	29.43	3.78	48.1	0.86	0.9	38.15	8,350											sub C	
W226190	(1)	34.39	13.76	32.19	19.66	7.23	38.06	0.64	2.28	38.03	6,914	0.00	0.75	1.53	---	0.0	---	2,160	2,230	2,260		lig A	Uncorrelated bed
PCU-1-M-1	(2)		20.97	49.07	29.96	5.16	58.01	0.97	3.48	11.41	10,538	0.00	1.15	2.33									0.45 m thick, 64 m depth
	(3)			62.09	37.91	6.53	73.40	1.23	4.40	14.44	13,336												
W226191	(1)	32.63	14.71	29.68	22.98	6.80	37.84	0.65	2.47	37.53	6,768	0.00	0.58	1.89	---	0.0	---	2,190	2,310	2,410		lig A	Uncorrelated bed
PCU-1-M-2	(2)		21.84	44.05	34.11	4.67	56.17	0.97	3.67	12.68	10,046	0.00	0.87	2.80									0.69 m thick, 89 m depth
	(3)			56.36	43.64	5.97	71.86	1.24	4.70	16.23	12,853	0.00	1.11	3.59									

Many more samples must be analyzed to adequately characterize the coals of the Baja Talamanca coal field, but the analytical results available indicate coals of a probable apparent rank of subbituminous C with medium ash and sulfur contents. This characterization should be used with caution until substantiated or modified by further analytical results.

CONCLUSIONS AND RECOMMENDATIONS

The rocks that are exposed in and near the Uatsi project area of the Baja Talamanca coal field represent essentially continuous deposition. The earliest of the rocks were deposited in marine waters at depths of several hundred meters and the latest in fluviatile conditions near the flanks of the area shedding the sediments. This transitional sequence--marine to marginal marine to paralic to fluviatile--proceeded rapidly, but with many lateral fluctuations of environments that produced repetitions of the resulting rocks. From a coal resource standpoint the net result is relatively small areas for deposition of coal-forming materials and relatively short, quiet depositional times for accumulation of organic material. The resulting coal beds are generally thin and commonly of limited areal extent. For these reasons, information about the stratigraphic framework of the coal-bearing rock sequence is extremely important because of the relationship to prediction of coal bed geometry.

Structurally, the rocks of the area are complexly folded and faulted. Synclines and anticlines with approximate east-west trending axes are broken by faults that dominantly trend northeast or northwest. The net result from a coal resource standpoint is the division of the area into relatively small--1 to 5 km^2--subareas in which the coal beds are bounded by outcrops or faults.

Twenty coal exploratory drill holes totaling about 4,000 m of penetration had been completed in the area as of August 1, 1985. The drill holes ranged in depth from 135 to 255 m, and averaged about 200 m.

Coal resources have been estimated for four reliably correlated coal beds in three subareas of the Uatsi project area. Two estimates of resources were made using the same information but adopting slightly different category parameters and interpretations of the data. The two estimates are the same in the demonstrated category (combined measured and indicated), but differ in the inferred assurance category. In the following discussion the later, USGS, estimate is quoted first, followed by the earlier, RECOPE, estimate in parentheses. All estimated measured resources are within 0.4 (0.25) km of a point of information, either drill hole, or outcrop. A total of 37 measurements at coal outcrops and measurements in 17 exploratory drill holes were used to derive the resources estimated.

A total of about 13 (17) million t of coal of probable apparent rank of subbituminous C, of which about 9.7 (8.7) million t is in the measured category, is estimated to be present in three subareas of the southern part of the Baja Talamanca coal field. The boundaries of each subarea are either faults or outcrops. About 2.5 (2.6) million t are estimated to be present in one coal bed (V-9), with an average thickness of about 1.6 m, in the subarea North Rio Carbon Volio, an area of about 1.2 km^2. About 2.5 (2.0) million t of the estimated total are in the measured category. The coal-bearing rocks are folded into an asymmetric anticline, and underground mining would almost certainly be required for recovery.

About 2.0 (3.1) million t of coal are estimated to be present in one bed (V-7), with an average thickness of about 0.9 m, in an area of about 1.7 km^2 in the subarea East Rio Carbon Volio. About 2.0 (1.9) million t of the estimated total are in the measured category. The coal-bearing rocks are inclined at an average angle of about 10° in a gently-folded sequence. Underground mining would be required for recovery of most of the resources, though a limited amount might be recovered by surface mining along the outcrop.

A total of about 8.6 (11.3) million t of coal is estimated to be present in two coal beds (V-1 and New V-9) in the subarea West Rio Carbon Volio. The lowest bed (V-1), which has an average thickness of about 0.9 m in the area of estimation (3.2 km^2), contains an estimated total of about 3.6 (5.1) million t, of which about 2.5 (1.8) million t are in the measured category. The upper bed (New V-9), which occurs about 140 m above the lower bed, is estimated to contain a total of almost 5.0 (6.2) million t of coal with an average thickness of about 1.5 m in an area of about 2.6 km^2. Of this total, about 2.7 (2.9) million t are in the measured category. The lower coal bed (V-1) would have to be recovered mainly by underground mining, but some surface mining might be done along the outcrop. The upper coal bed (New V-9) is recoverable by surface mining in part of the area of about 0.4 km^2 with an overburden factor of less than 20 to 1. Another coal bed (V-5?) as much as 1 m thick occurs about 30 m above the upper coal bed at one information point, but the lateral continuity and thickness of this bed must be further established, and no resources were estimated for it. Obviously, the presence, or absence, of the V-5? bed can affect planning for surface recovery of the New V-9 bed.

In addition to the coal beds for which resources were estimated, other coal beds are present in the three subareas cited above. However, the extent, thickness, and quality of these other coal beds remains to be determined. Other subareas of the project area contain coal beds that might prove to be of economic interest. However, coal bed continuity and thicknesses have not been determined, thus no resources were estimated in other subareas at this time. Areas of the Baja Talamanca coal field adjoining and adjacent to the Uatsi project area also contain coal beds about which little is known.

Analyses of 16 samples from the Uatsi project area show apparent ranks of lignite B to high volatile C bituminous, but five samples are of apparent subbituminous C rank and four samples of apparent lignite A rank. Average ash and sulfur contents of the samples are 13.8 and 1.7 percent, respectively. Though the following characterization is subject to change as more analyses are completed, indications are that the coal of the Uatsi project area has an apparent rank of subbituminous C and medium ash and sulfur content.

The proposed drill holes shown on figure 2 are designed to yield needed information in those parts of the area that have already been partially explored and to begin the exploration needed in the adjoining parts of the Uatsi project area and the remainder of the Baja Talamanca coal field. In particular, drill holes are needed to provide data to evaluate the surface mining potential for the New V-9 coal bed and to provide correlation information in all parts of the project area so resources may be evaluated for more of the coal beds known to be present.

An excellent coal quality laboratory of international comparability is absolutely essential to provide information needed in all aspects of further coal exploration, development, exploitation, and utilization. A very good start has been made, but equipment, space, and perhaps training will be required for laboratory personnel in order to increase the analytical capability.

The ability to do bore-hole geophysical logging is absolutely necessary in modern coal exploratory drill programs. At this point, the equipment being used for making natural radioactivity (gamma), density (gamma-gamma), resistivity, and caliper logs is on loan from the USGS and must soon be returned. RECOPE must obtain its own geophysical logging units as soon as possible and should, if possible, acquire two units of the same type for backup capability and use as exploration proceeds in other coal fields of Costa Rica.

Other research will be needed in the Uatsi project area, such as studies of the mechanical properties of the rocks of the Middle Member of the Gatun Formation to evaluate possible mining methods and equipment requirements. Studies of the hydrology of the area are also needed for mine planning.