Chapter 2

World Coal Quality Inventory: Argentina

by William E. Brooks, Robert B. Finkelman, Jason C. Willett, and Ivette E. Torres

U.S. Geological Survey, Mail Stop 956, Reston, VA 20192, USA

Chapter 2 of

World Coal Quality Inventory: South America

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Metric Conversion Factors

Imperial Units	SI conversion
acre	4,046.87 square meters
acre-foot	1,233.49 cubic meters
British thermal unit (Btu)	1,005.056 joules
British thermal unit / pound (Btu / lb)	2,326 joules / kilogram
Fahrenheit (ºF)	Centigrade (ºC) = [(ºF-32)x5]/9
foot (ft)	0.3048 meters
inch (in)	0.0254 meters
mile (mi)	1.609 kilometers
pound (lb)	0.4536 kilograms
short ton (ton)	0.9072 metric tons
short tons / acre-foot	0.7355 kilograms / cubic meter
square mile (mi^2)	2.59 square kilometers

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Introduction

The U.S. Geological Survey (USGS), in cooperation with most of the world's coal-producing countries, has undertaken a project called the World Coal Quality Inventory (WoCQI). The WoCQI currently contains coal quality and ancillary information on samples obtained from major and minor coal-producing regions throughout the world (Finkelman and Lovern, 2001a, b). Sample collection and analysis for the WoCQI are described in the Executive Summary (Chapter 1, this volume). Only 7 samples of Argentina coal were obtained for this study.

Argentina Coal

Alvarado (1980) states that South America has only approximately 0.5% of the world's supply of coal, although the Energy Information Administration (EIA) reports in 2005 that total recoverable coal in South America is 2.2% of the world's coal (EIA, 2005). However, occurrences of coal and other organic-enriched strata such as bituminous schists and lignite, are widely distributed in Argentina (Borrello, 1956; Weaver and Wood, 1994; Lopes and Ferreira, 2000). Argentina ranks in the top 40 countries worldwide in coal reserves (34^{th} according to Agramonte and Diaz, 1983 and 39^{th} according to EIA, 2005).

Bergmann (1978) and Bergmann and Xicoy (1989) provide a geologic overview of Argentine coal and discuss coal resources in Argentina. Torres (2001) provides recent information on the mineral industry in Argentina, including coal; these references may be of interest to the reader.

Geology of Coal Areas

Coal mines and occurrences in Argentina are reported to range from 41 (Weaver and Wood, 1994) to as many as 850 (Alvarado, 1980). Argentine coals are found in Triassic, Jurassic, early

Tertiary, and Neogene sedimentary rocks in four major coal basins (Bergmann and Xicoy, 1989). Historically, both the Yacimientos Carboniferos de Rio Turbio deposit in Santa Cruz Province and the Pico Quemado deposit in Rio Negro Province (fig. 1) have been important.

The Rio Turbio deposit is considered to be the national coal capital of Argentina (Inter Patagonia, 2002) and is included in the Austral Basin, which is mainly a thick marine sequence without major tectonic disturbances (Malumian and Carames, 1997). The Austral Basin is believed to be an extension of the Magallanes Basin in Chile (see fig. 1, Chapter 4, this volume). At the Rio Turbio mine (fig. 2), five Paleogene, sub-bituminous coal bearing units, locally referred to as "mantos", are present in gently east-dipping (5-10°) marine and continental sediments (Patagonian Formation). Yacimientos Carboniferos de Rio Turbio underground mined the five coal-bearing units, called from bottom to top: manto inferior, manto superior, manto B, manto A, and manto Dorotea. The uppermost of these units, manto Dorotea (fig. 3) is 1.92 m thick and is the last unit being mined. Mineral occurrences and regional geology of the Rio Turbio area are compiled on a recent map by Malumian and others (2000).

Coal at Pico Quemado, Rio Negro province was first described in 1897. In the 1950s, five mines with 3,800 m of underground workings were mined by over a hundred workers (Borrello, 1956). However, the site has been abandoned (fig. 4) and the mines have collapsed. Four coal beds that are 1.1-5.0 m in thickness are present in Miocene continental sediments that have been folded by regional compression with only minor faulting. Intermediate composition volcanic rocks have intruded and overlie the coal-bearing sedimentary section. The regional geology and mineral occurrences have been described by Glacosa and others (2000).

Coal Resource Estimates

Coal resources in Argentina are estimated to be 465 million metric tons of which 460 million metric tons are mainly in the Rio Turbio and Pico Quemado mines (Alvarado, 1980). Resource estimates for 18 coal mines in Argentina are listed in Weaver (1993). According to the Energy Information Administration (2006), recoverable coal reserves were estimated to be 426 million metric tons in 2003.

A drilling program carried out in the 1950s at Pico Quemado indicated reserves of 2,640,000 metric tons (Bergmann and Xicoy, 1989). Analytical data from Borrello (1956) indicate an ash yield of 10.1-25.4 percent, sulfur content of 0.5-0.6 percent, and calorific values of 6,000-7,000 Btu/lb. Pico Quemado was a small coal mining operation that was abandoned in the 1990s (fig. 4). However, Bergmann (1978) considers the coal to have valuable coking qualities.

The Rio Turbio deposit was first visited in 1887 (Borrello, 1956) and in 1994 the government privatized the coal company operations that became Yacimientos Carboniferos Fisicales (YCF) (Enerdata, 1998). Borello (1956) estimated resources of 370,500,000 metric tons of coal with ash yields of 11.0-24.2 percent at Rio Turbio. YCF indicates that the average sulfur content is 0.8 percent, with an average ash yield of 13 percent, and average calorific value of 6,500 Btu/lb.

Coal Production

Coal production in Argentina steadily declined since 1999 and ceased in 2003. Table 1 contains annual production data in metric tons from Daniel Cameron, the Argentine Secretary of Energy, for the period of 1995-2003.

Coal Uses

In South America, coal was used during pre-Inca times for metallurgy (Agramonte and Diaz, 1983) and decorative purposes (Burger, 1992; Larco, 2001). In 2001, approximately 70 metric tons of coal were moved daily by rail from Rio Turbio to the port of Rio Gallegos for transport by ship to Buenos Aires for metallurgical use. Of the 27 power plants in Argentina that rely on fossil fuels only one station, San Nicolas in Santa Fe province, uses coal, all others rely on oil and gas. There is minor domestic use of coal in rural areas of the region.

Coal Trade

Import and export tonnages presented in Table 2 are from Daniel Cameron (personal communication), the Argentine Secretary of Energy. Approximately 420,000 metric tons, or 2 percent, of the metallurgical coal exported from New South Wales, Australia goes to Argentina (Mineral Resources of New South Wales, 2001).

Coal Quality

Data given in Borrello (1956) and Bergmann and Xicoy (1989) are the most recent analytical data on Argentinean coal from the Rio Turbio and Pico Quemado deposits. Data for trace elements were not available. A review of internal Yacimientos Carboniferos Fisicales reports (Bergmann, 1991, 1992; Borrello, 1953; Cabrera, 1980; Calliari, 1955; Luengas, 1949; Piatnitzky, 1947, 1949, 1953; and Sarris, 1946) also yielded little recent information on coal chemistry. Regionally, however, Helle and others (2000) report trace element data on coals to the west, in the Magallanes Basin in southern Chile.

Therefore, as part of the WoCQI, three samples from Rio Turbio and four samples from Pico Quemado were obtained during site visits by USGS staff and analyzed by the U.S. Geological Survey for major oxide and trace-element content. Proximate and ultimate analyses and sulfur-form data were obtained by a contracted commercial laboratory.

The limited number of samples (seven samples from two locations) and sample collection methods (two are full channel samples and the rest are grab samples) preclude any meaningful discussion of geologic controls on coal quality, vertical or lateral coal quality trends, and statistical treatment of the analytical data. Therefore, only general comments will be provided on the quality of the Argentina coals. Field descriptions for the samples are in Table 3. The proximate, ultimate analysis and sulfur form data are in Table 4, major element oxides are in Table 5, and trace element data are in Table 6.

Samples BA0201 and BA0301 were the only samples collected from an active coal mine (Rio Turbio) and are representative of mineable coal. Calorific values (Table 4) on a moist, mineral-matter free basis are 10,430 and 11,588 Btu/lb indicating a rank of subbituminous A to high volatile C bituminous coal (American Society for Testing and Materials, 2003). Ash yields for these two samples are 12 and 16.7 weight percent. Total sulfur contents were 0.43 and 1.6 weight percent.

In Table 5, the Argentine coal samples have relatively high concentrations of CaO (8.2-12 weight percent), MgO (1.3-1.6), and Fe_2O_3 (6.6-11.1; in excess of the iron required for pyrite) indicating the presence of carbonates. The relatively high manganese contents (140-254 ppm; Table 6) are consistent with the presence of iron-bearing carbonates.

Most of the trace elements (Table 6) are present at relatively low concentrations. The sole exception is boron, which ranges from 121-185 ug/g.

Coal Utilization Impacts

The minor amount of previous coal mining in Argentina precludes widespread environmental impacts. No element, including gold and silver, was present at concentrations high enough to offer economic byproduct recovery potential. Table 6 shows that the concentrations of the elements of environmental and human health concern (As, Be, Cd, Cr, Hg, Ni, Pb, Sb, Se, Te, Tl, and U) are all relatively low. In addition, the relatively low sodium and phosphorous content (Table 5) and chlorine content (Table 6) indicate a low potential for technological problems such as fouling and corrosion.

Coalbed Methane

No information was found on coalbed methane resources or production in Argentina.

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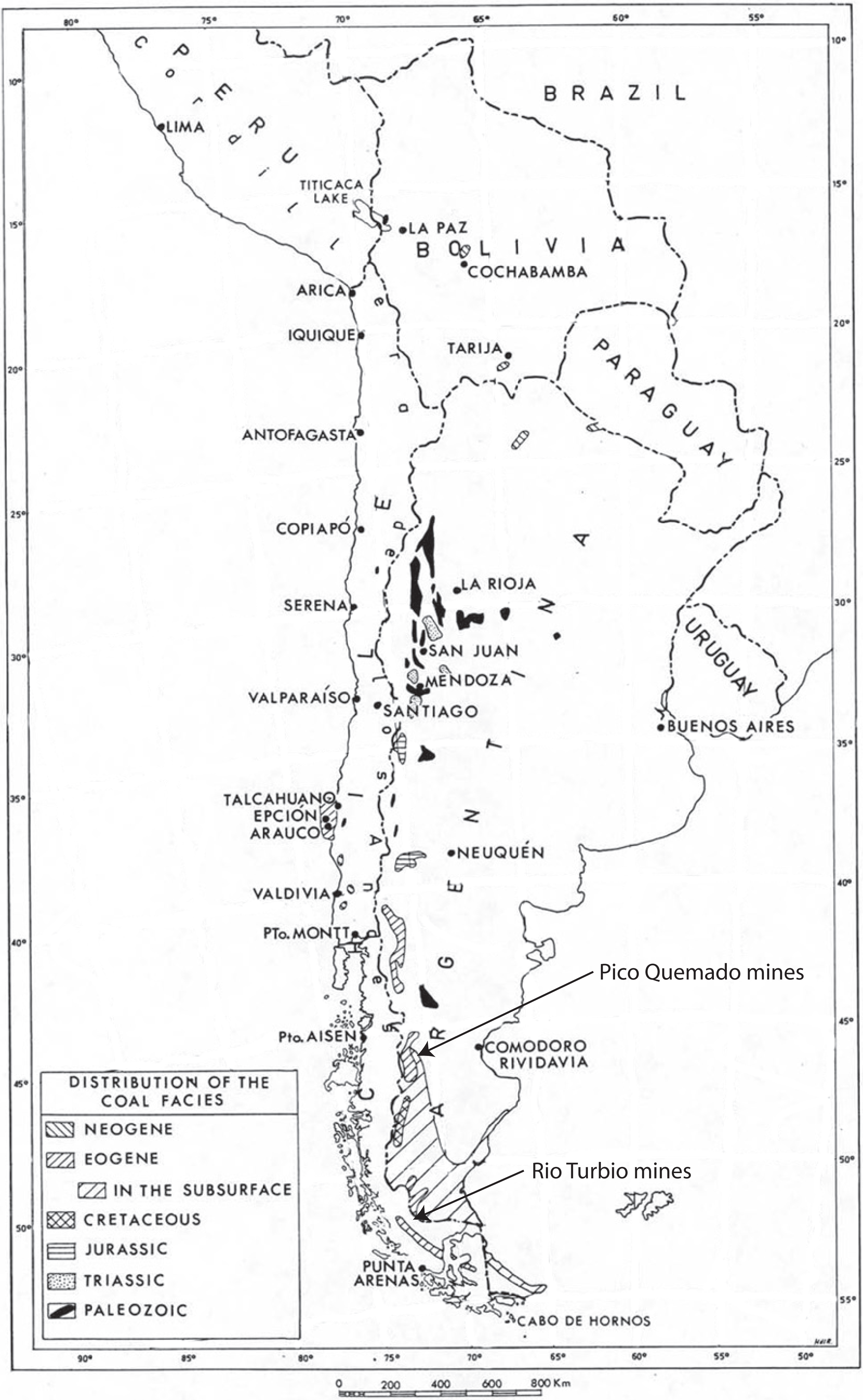

Figure 1. Distribution of coal units in Argentina (Borrello, 1956).

Figure 2. East dipping Tertiary section near entrance to Rio Turbio, Santa Cruz province

Figure 3. Manto Dorotea coal bed, Rio Turbio, Santa Cruz province

Figure 4. Abandoned mining camp of Pico Quemado, Rio Negro province.

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Table 1. Argentina bituminous coal production from 1995-2003 (thousand metric tons). Source: Daniel Cameron, Argentine Secretary of Energy.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Production	304	311	250	218	353	273	196	57	0

Table 2. Argentina import and export coal trade data from 1995-2002 (thousand metric tons); ND=no data. Source: Daniel Cameron, Argentine Secretary of Energy.

Year	1995	1996	1997	1998	1999	2000	2001	2002
Imports	466	272	231	210	170	338	215	825
Exports	4	5	5	6	0	10	0	ND

Table 3. Location information for 7 Argentinean coal samples.

Field id	Country	Province	Latitude	Longitude	Mine	Sample type	Description
BA0101	Argentina	Rio Turbio	51° 32.497 S	72° 19.663 W	Rio Turbio	channel	Surface outcrop of manto Inferior, 1m thick, collected at depth of 20 cm into outcrop, dip approximately 5° E.
BA0201	Argentina	Rio Turbio	51° 32.388 S	72° 15.754 W	Rio Turbio	channel	entrance to the mine, channel sample taken underground from active face of manto Dorotea, approximately 2 meters thick, Galeria 1/7, approximately 5 km into the mine.
BA0301	Argentina	Rio Turbio	51° 32.388 S	72° 15.754 W	Rio Turbio	channel	entrance to the mine, channel sample taken underground from active face of manto Dorotea, approximately 2 meters thick, Nicho Inferior, 51D, approximately 5 km into the mine.
BA0401	Argentina	Pico Quemado	41° 34.766 S	71° 01.358 W	Pico Quemado	grab	sample taken 50 centimeters in abandoned mine waste, not outcrop.
BA0501	Argentina	Pico Quemado	41° 34.756 S	71° 01.351 W	Pico Quemado	grab	sample taken 50 centimeters in abandoned mine waste near an adit, not outcrop.
BA0601	Argentina	Pico Quemado	41° 34.665 S	71° 01.340 W	Pico Quemado	grab	sample taken from coal exposed at creek level, approximately 30-40 centimeters thick.
BA0701	Argentina	Pico Quemado	41° 34.766 S	71° 01.358 W	Pico Quemado	grab	same location as above, sulfides present, sample very hard and brittle, possibly altered by nearby hypabyssal volcanic rocks.

Table 4. Proximate and ultimate analyses, gross calorific value, and forms of sulfur on an as-received basis for 7 Argentinean coal samples.

[Abbreviations: Moist=moisture; %=weight percent; VM=volatile matter; FC=fixed carbon; Ash=ash yield; °C=degrees Centigrade; H=hydrogen; C=carbon; N=nitrogen; S=sulfur; O=oxygen; CV=gross calorific value; Btu/lb=British thermal units per pound; MJ/kg=Megajoules per kilogram; Sulf=sulfate sulfur; Pyr Sulf=pyritic sulfur; Org Sulf=organic sulfur; nd=not determined.]

	Proximate Analyses				Ultimate Analyes							Forms of Sulfur		
Field Number	Moist (%)	VM (%)	FC (%)	Ash (%) (750°C)	H (%)	C (%)	N (%)	S (%)	O (%)	CV (Btu/lb)	CV (MJ/kg)	Sulf (%)	Pyr Sulf (%)	Org Sulf (%)
BA0101	10.77	30.34	33.69	25.20	3.96	49.62	0.89	0.45	9.11	8,930	21	0.01	0.07	0.37
BA0201	10.11	36.49	36.73	16.67	4.53	57.83	0.98	0.43	9.45	10,430	24	0.01	0.13	0.29
BA0301	7.65	42.37	37.93	12.05	5.14	63.25	1.06	1.60	9.25	11,590	27	0.01	0.77	0.82
BA0401	17.61	18.91	16.45	47.03	1.79	23.64	0.72	0.16	9.05	3,880	9.0	0.01	0.03	0.12
BA0501	8.18	25.16	26.34	40.32	3.25	38.92	1.10	0.29	7.94	7,040	16	0.00	0.04	0.25
BA0601	9.80	14.68	10.35	65.17	1.71	16.05	0.48	0.16	6.63	2,830	6.6	0.01	0.05	0.10
BA0701	3.96	nd	nd	68.96	0.43	11.51	0.18	1.13	13.83	850	2.0	0.06	0.89	0.18

Table 5. Analytical data (on an as-determined, ash basis) for ash yield and major- and minor- oxides for 7 Argentinean coal samples.

[Abbreviations: Ash = ash yield; %=weight percent; °C=degrees Centigrade;Total = sum of oxides on an ash basis; nd=not determined; <=less than. Values were derived following methods described in Bullock and others (2002).]

Field Number	Ash (525°C) (%)	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	Fe_2O_3 (%)	TiO_2 (%)	P_2O_5 (%)	SO_3 (%)	Total
BA0101	27.8	56.8	31.1	3.70	0.870	0.140	0.340	2.40	2.40	0.040	1.10	98.9
BA0201	18.8	44.8	22.3	11.6	1.50	0.760	0.280	6.4	1.70	0.050	4.10	93.9
BA0301	12.8	42.2	22.4	8.00	1.30	0.540	0.240	10.8	1.30	0.050	7.20	94.0
BA0401	54.8	70.4	23.1	1.90	0.610	0.070	0.280	1.30	1.20	0.100	0.770	99.7
BA0501	43.5	64.7	28.5	1.10	0.360	0.150	0.360	2.10	1.40	0.830	0.230	99.7
BA0601	71.8	71.4	30.1	0.760	0.650	0.110	0.460	2.10	1.70	0.100	<0.02	107.4
BA0701	79.0	5.80	2.10	18.3	1.40	0.030	0.040	67.0	0.120	0.680	3.20	98.7

Table 6. Major-, minor-, and trace- element data for 7 Argentinean coal samples calculated to a dry, whole-coal basis.

[All values in µg/g (ppm), except ash yield, Si, Al, Ca, Mg, Na, K, Fe, Ti, and P which are in weight percent. Ash=ash yield, %=weight percent, °C=degrees Centigrade. Values were derived following methods described in Bullock and others (2002).]

Field Number	Ash (%) (525°C)	Si (%)	Al (%)	Ca (%)	Mg (%)	Na (%)	K (%)	Fe (%)	Ti (%)	P (%)
BA0101	28.6	7.60	4.71	0.757	0.150	0.0297	0.0808	0.481	0.412	0.00500
BA0201	19.4	4.06	2.29	1.61	0.175	0.109	0.0451	0.868	0.198	0.00420
BA0301	13.2	2.60	1.56	0.754	0.103	0.0528	0.0263	0.996	0.103	0.00290
BA0401	56.8	18.7	6.95	0.772	0.209	0.0295	0.132	0.517	0.409	0.0248
BA0501	44.2	13.4	6.67	0.348	0.096	0.0492	0.132	0.649	0.371	0.160
BA0601	73.1	24.4	11.6	0.397	0.287	0.0597	0.279	1.07	0.745	0.0319
BA0701	80.0	2.17	0.889	10.5	0.675	0.0178	0.0266	37.5	0.0575	0.237

Field Number	As (µg/g)	B (µg/g)	Ba (µg/g)	Be (µg/g)	Bi (µg/g)	Cd (µg/g)	Co (µg/g)	Cr (µg/g)	Cs (µg/g)	Cu (µg/g)	Ga (µg/g)
BA0101	0.830	318.	49.5	2.26	0.195	0.0916	9.28	15.6	0.272	47.8	15.2
BA0201	4.09	121.	11.6	0.368	0.0814	0.0194	11.6	5.76	0.271	18.1	5.95
BA0301	2.36	185.	3.19	0.330	0.0554	0.0224	3.47	4.24	0.277	17.1	3.65
BA0401	0.568	<12.0	213.	2.05	0.0966	0.0966	12.1	32.9	0.796	22.7	12.4
BA0501	0.752	<8.90	553.	1.77	0.106	0.124	13.7	32.5	1.15	55.7	13.2
BA0601	1.02	<15.0	296.	1.97	0.132	0.0951	13.2	50.7	2.56	18.6	20.2
BA0701	42.1	<16.0	197.	1.52	<0.0800	<0.0800	34.2	59.3	0.176	<1.60	1.60

Table 6. Major-, minor-, and trace- element data for 7 Argentinean coal samples calculated to a dry, whole-coal basis—continued.

Field Number	Ge (µg/g)	Hg (µg/g)	Li (µg/g)	Mn (µg/g)	Mo (µg/g)	Nb (µg/g)	Ni (µg/g)	Pb (µg/g)	Rb (µg/g)	Sb (µg/g)	Sc (µg/g)
BA0101	5.93	0.021	14.5	52.7	1.09	2.86	<1.20	7.19	2.35	0.630	23.2
BA0201	0.814	0.031	8.12	254.	1.82	2.46	2.33	4.17	2.27	0.112	5.23
BA0301	0.699	0.18	7.72	140.	0.646	1.04	1.38	2.69	1.58	0.132	4.65
BA0401	5.40	0.031	20.5	28.8	0.910	4.60	45.4	6.20	6.31	0.506	10.3
BA0501	4.11	0.081	25.6	61.9	0.752	4.73	19.1	13.4	7.12	0.663	9.33
BA0601	3.95	0.092	44.6	26.2	0.468	7.17	24.3	10.7	11.9	0.314	13.9
BA0701	2.80	0.96	4.64	4770.	1.92	0.880	<3.20	2.88	1.04	0.432	7.60

Field Number	Se (µg/g)	Sn (µg/g)	Sr (µg/g)	Te (µg/g)	Th (µg/g)	Tl (µg/g)	U (µg/g)	V (µg/g)	Y (µg/g)	Zn (µg/g)	Zr (µg/g)
BA0101	1.0	2.55	31.8	0.132	2.49	0.143	0.945	214.	26.2	30.9	185.
BA0201	0.88	1.05	68.6	0.0640	2.44	0.176	0.698	39.3	2.13	10.8	48.8
BA0301	0.84	0.659	44.7	0.0554	1.48	0.0593	0.488	27.7	4.67	8.37	29.9
BA0401	0.25	2.16	76.7	<0.0570	<4.60	0.0910	0.966	137.	16.9	30.4	287.
BA0501	0.21	5.22	265.	<0.0450	3.89	0.115	1.19	143.	7.60	29.1	183.
BA0601	0.65	4.39	192.	<0.0740	<5.90	0.117	1.17	175.	<0.740	30.6	313.
BA0701	1.2	<2.40	150.	<0.0800	<6.40	1.36	0.24	52.6	38.8	103.	89.6