JOHN V. WALTHER

EARTH'S NATURAL RESOURCES

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About the cover: A bucket wheel excavator operating in a strip mine near Lausitz, Germany, removing overburden layers of soil to expose lignite coal below. Bucket wheel excavators have a rotating wheel with a series of buckets attached. The upswing movement of the wheel causes the buckets to scoop soil or lignite, carrying it to the back of the wheel where it falls on a conveyor belt for removal. These 13,000 metric ton vehicles move on caterpillar tracks, cost more than U.S. $100 million each, can remove more than 75,000 meters^3 of material a day, and require four to five operators.

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Preface

> **"Man shapes himself through decisions that shape his environment."**
>
> ***– René Dubos***

Because of the intellect we possess, our evolutionary rise is different from other species on Earth. As civilization advances, humankind can decide about how to use the earth's natural resources it requires. Rather than taking the evolutionary path of easiest maximum exploitation, humankind can make choices. Potentially, humans can exploit natural resources so they can supply needs far into the future. To do this, they must understand resource availability and the extent of demand.

Exploitation of natural resources creates employment and wealth. Today, worldwide production of natural resources typically is undertaken with a capitalistic system of supply and demand. This works reasonably well when resources are abundant and widely distributed, but as the 1973–1974 Arab oil embargo demonstrated, political concerns can be problematic when resources are limited or confined to certain countries. As demand increases and the supply of a key natural resource becomes restricted, increased political disruption can occur. Knowledge of resource location and availability becomes more important to anticipate and address these concerns.

The rise in resource prices indicates a limited supply. Whether this is predicted to be temporary or permanent depends on an understanding of future supply sources. This knowledge is important for the informed citizen. This understanding cannot be divorced from an understanding of future population growth and, therefore, demand as well as the environmental impact of resource extraction and usage. I hope that *Earth's Natural Resources* will impart the needed information by considering where natural resources occur, how they are concentrated and extracted, and the extent of their supply and usage.

The book has a U.S. bias in that many of the examples are derived from the United States, but the development should be of interest to a wider audience. The book is appropriate for a student with a scientific background equivalent to a strong U.S. high school education and some lower division college courses in physical geology. To assist those with less experience, Chapter 1 provides a short review of some terms. Important terms, when first used, are *italicized* and provided in a glossary at the end of the book. In many U.S. curriculums, the book fits into a lower division college major's course in Earth or Environmental Science or as a background resource course in Civil Engineering. Each chapter provides problems to help the reader develop a deeper understanding of the material covered. Answers to these problems are available from the publisher.

Instructor's Resources

A downloadable **PowerPoint® Image Bank** is available to instructors. This resource provides the book's illustrations, photographs, and tables (to which Jones & Bartlett holds the copyright or has permission to reproduce digitally) inserted into PowerPoint slides. These images and tables can be easily copied into existing lecture slides.

Also available for download is the **PowerPoint® Lecture Outline** presentation package. This provides lecture notes and images for each chapter of *Earth's Natural Resources*. Instructors with Microsoft PowerPoint software can customize the outlines, art, and order of each presentation.

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Table of Elements

Listed for the given element are the chapter where it is discussed, its atomic number, atomic weight, common valence states, and average abundance in the continental crust and seawater.w

ELEMENT	CHAPTER	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	COMMON VALENCE STATES	AVERAGE CONTINENTAL CRUST	SEAWATER
Actinium	-	Ac	89	227.03	+3	-	-
Aluminum	6	Al	13	26.98	+3	8.2%	8×10^{-4} ppm
Americium	-	Am	95	(243)	+3,+4,+5,+6	-	-
Antimony	9	Sb	51	121.75	+3,+5,−3	0.2 ppm	0.15 ppb
Argon	11	Ar	18	39.95	0	-	-
Arsenic	9	As	33	74.92	+3,+5,−3	2.1 ppm	1.7 ppb
Astatine	-	At	85	(210)	-1	-	-
Barium	10	Ba	56	137.34	+2	340 ppm	0.014 ppm
Berkelium	-	Bk	97	(247)	+3,+4	-	-
Beryllium	9	Be	4	9.01	+2	1.9 ppm	2×10^{-7} ppm
Bismuth	9	Bi	83	208.98	+3,+5	25 ppb	0.02 ppb
Boron	11	B	5	10.81	+3	8.7 ppm	4.5 ppm
Bromine	11	Br	35	79.91	+1,+5,−1	3 ppm	67 ppm
Cadmium	8	Cd	48	112.30	+2	0.15 ppm	0.08 ppb
Calcium	6	Ca	20	40.08	+2	5.0%	413 ppm
Californium	-	Cf	98	(251)	+3	-	-
Carbon	2–3, 10	C	6	12.01	+2,+4,−4	0.18%	28 ppm
Cerium	9	Ce	58	140.12	+3,+4	60 ppm	0.0035 ppb
Cesium	9	Cs	55	132.90	+1	1.9 ppm	0.29 ppb

ELEMENT	CHAPTER	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	COMMON VALENCE STATES	AVERAGE CONTINENTAL CRUST	SEAWATER
Chlorine	11	Cl	17	35.45	+1,+5,+7,−1	170 ppm	1.95%
Chromium	7	Cr	24	52.00	+2,+3,+6	140 ppm	0.2 ppb
Cobalt	7	Co	27	58.93	+2,+3	30 ppm	0.002 ppb
Copper	8	Cu	29	63.54	+1,+2	68 ppm	0.3 ppb
Curium	-	Cm	96	(247)	+3	-	-
Dysprosium	9	Dy	66	162.50	+3	6.2 ppm	0.0011 ppb
Einsteinium	-	Es	99	(254)	+3	-	-
Erbium	9	Er	68	167.26	+3	3.0 ppm	9.2×10^{-4} ppb
Europium	9	Eu	63	151.96	+2,+3	1.8 ppm	1.5×10^{-4} ppb
Fermium	-	Fm	100	(257)	+3	-	-
Fluorine	8	F	9	19.00	−1	540 ppm	1.3 ppm
Francium	-	Fr	87	(223)	+1	-	-
Gadolinium	9	Gd	64	157.25	+3	5.2 ppm	0.001 ppb
Gallium	9	Ga	31	69.72	+3	19 ppm	0.02 ppb
Germanium	9	Ge	32	72.59	+2,+4	1.4 ppm	0.005 ppb
Gold	9	Au	79	196.97	+1,+3	3.1 ppb	0.0049 ppb
Hafnium	5	Hf	72	178.49	+4	3.3 ppm	$<$ 0.007 ppb
Helium	11	He	2	4.00	0	-	-
Holmium	9	Ho	67	164.93	+3	1.2 ppm	2.8×10^{-4} ppb
Hydrogen	3	H	1	1.01	+1,−1	0.15%	10.82%
Indium	9	In	49	114.82	+3	0.16 ppm	1×10^{-4} ppb
Iodine	11	I	53	126.90	+1,+5,+7,−1	0.49 ppm	0.056 ppm
Iridium	9	Ir	77	192.20	+3,+4	0.4 ppb	1×10^{-5} ppb
Iron	6	Fe	26	55.85	+2,+3	6.3%	0.06 ppb
Krypton	11	Kr	36	83.80	0	-	-
Lanthanum	9	La	71	174.97	+3	34 ppm	0.0045 ppb
Lead	8	Pb	82	207.19	+2,+4	10 ppm	0.002 ppb
Lithium	11	Li	3	6.94	+1	17 ppm	0.17 ppm
Lutetium	9	Lu	71	174.97	+3	350 ppb	1.4×10^{-4} ppb
Magnesium	6	Mg	12	24.31	+2	2.90%	0.129%
Manganese	6	Mn	25	54.94	+2,+3,+4,+7	0.11%	0.3 ppb
Mendelevium	-	Md	101	(258)	+2,+3	-	-

ELEMENT	CHAPTER	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	COMMON VALENCE STATES	AVERAGE CONTINENTAL CRUST	SEAWATER
Mercury	8	Hg	80	200.59	+1,+2	67 ppb	0.001 ppb
Molybdenum	7	Mo	42	95.95	+4,+6	1.1 ppm	0.011 ppm
Neodymium	9	Nd	60	144.24	+3	33 ppm	0.0042 ppb
Neon	11	Ne	10	20.18	0	-	-
Neptunium	-	Np	93	237.05	+3,+4,+5,+6	-	-
Nickel	7	Ni	28	58.71	+2,+3	980 ppm	0.5 ppb
Niobium	9	Nb	41	92.91	+3,+5	17 ppm	< 0.005 ppb
Nitrogen	11	N	7	14.01	+1,+2,+3,+4,	20 ppm	15.5 ppm
Nobelium	-	No	102	(259)	+2,+3	-	-
Osmium	9	Os	76	190.20	+3,+4	1.8 ppb	1×10^{-5} ppb
Oxygen	11	O	8	16.00	−2	46%	85.84%
Palladium	9	Pd	46	106.40	+2,+4	6.3 ppb	2×10^{-4} ppb
Phosphorus	11	P	15	30.97	+3,+5,−3	0.10%	0.071 ppm
Platinum	9	Pt	78	195.09	+2,+4	3.7 ppb	0.05 ppb
Plutonium	5	Pu	94	(244)	+3,+4,+5,+6	-	-
Polonium	-	Po	84	(209)	+2,+4	-	-
Potassium	11	K	19	39.10	+1	1.5%	399 ppm
Praseodymium	9	Pr	59	140.91	+3	8.7 ppm	0.001 ppb
Promethium	9	Pm	61	(145)	+3	-	-
Protactinium	-	Pa	91	231.04	+4,+5	-	-
Radium	5	Ra	88	226.03	+2	-	-
Radon	5	Rn	86	(222)	0	-	-
Rhenium	9	Re	75	186.20	+4,+6,+7	2.6 ppb	0.004 ppb
Rhodium	9	Rh	45	102.90	+3	0.7 ppb	7 ppb
Rubidium	-	Rb	37	85.47	+1	60 ppm	0.12 ppm
Ruthenium	9	Ru	44	101.07	+3	1 ppb	7×10^{-4} ppb
Samarium	9	Sm	62	150.35	+2,+3	6 ppm	8.4×10^{-4} ppb
Scandium	9	Sc	21	44.96	+3	26 ppm	6.7×10^{-4} ppb
Selenium	10	Se	34	78.96	+4,+6,−2	50 ppb	0.13 ppb
Silicon	6	Si	14	28.09	+2,+4,−4	27%	2.8 ppm
Silver	9	Ag	47	107.87	+1	80 ppb	0.0027 ppb
Sodium	11	Na	11	22.99	+1	2.30%	1.08%

ELEMENT	CHAPTER	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	COMMON VALENCE STATES	AVERAGE CONTINENTAL CRUST	SEAWATER
Strontium	11	Sr	38	87.62	+2	360 ppm	7.6 ppm
Sulfur	11	S	16	32.06	+4,+6,−2,−1,0	420 ppm	900 ppm
Tantalum	9	Ta	73	180.95	+5	1.7 ppm	< 0.0025 ppb
Technetium	-	Tc	43	98.91	+4,+6,+7	-	-
Tellurium	9	Te	52	127.60	+4,+6,−2	1 ppb	8×10^{-4} ppb
Terbium	9	Tb	65	158.92	+3	0.95 ppm	1.7×10^{-4} ppb
Thallium	9	Tl	81	204.37	+1,+3	0.53 ppm	0.01 ppb
Thorium	5	Th	90	232.04	+4	6 ppm	6×10^{-5} ppb
Thulium	9	Tm	69	168.93	+3	0.45 ppm	1.3×10^{-4} ppb
Tin	8	Sn	50	118.69	+2,+4	2.2 ppm	5×10^{-4} ppb
Titanium	6	Ti	22	47.90	+2,+3,+4	0.66%	< 0.96 ppb
Tungsten	7	W	74	183.85	+6	190 ppm	0.1 ppb
Uranium	5	U	92	238.03	+3,+4,+5,+6	1.8 ppm	3.1 ppb
Vanadium	7	V	23	50.94	+2,+3,+4,+5	190 ppm	1.2 ppb
Xenon	11	Xe	54	131.30	0	-	-
Ytterbium	9	Yb	70	173.04	+2,+3	2.8 ppm	9.0×10^{-4} ppb
Yttrium	9	Y	39	88.90	+3	29 ppm	0.007 ppb
Zinc	8	Zn	30	65.37	+2	79 ppm	0.4 ppb
Zirconium	5	Zr	40	91.22	+4	130 ppm	0.03 ppb

Values in parentheses are the atomic weight of the longest-lived isotope. Crustal abundance from: www.webelements.com/periodicity/abundance_crust/ and seawater composition from www.seafriends.org.nz/oceano/seawater.htm.

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