Publisher's Note

This third edition of the four-volume *Encyclopedia of Global Resources* comes ten years after the American Library Association praised the first edition as an Outstanding Reference Source of 1999. Now with over 580 entries, topics have been added and updated to extend their scope to our global economy in 2019. Hundreds of charts, tables, graphs, and sidebars support the text, and dozens of appendixes illustrate the text, providing students with worldwide insights into where we derive our mineral, biological, and energy resources; how they are processed; for what purposes they are used; and where they stand in our current economy. The coverage touches not only on the economic applications and benefits of natural resources but also on their processing, their management, the environmental impact of their extraction, and trends in their availability—all in easily understood language. This new edition includes 40 overviews of top resource nations and their significance in the global context. Specific minerals, organizations, historical events, and biographies are included as well as articles on energy and ecological resources. Appendixes provide both alphabetical and periodic tables of the elements, along with lists of Major U.S. Mineral Resources, Major U.S. Mineral Resources by State, Major Canadian Mineral Resource Production and Values, Major Worldwide Mineral Resources and Producers, Major Worldwide Resources by Country, a Time Line, a Glossary, a Bibliography, and a list of Web Sites.

Content Definition

The term "natural resources" has been in general use since the late nineteenth century, and for many decades discussions of natural resources have formed an important part of history, anthropology, and social studies curricula. In the most basic sense, natural resources have long been defined as naturally occurring raw materials and phenomena—timber, flowing water, and minerals such as iron and coal—that are economically useful to humans, particularly those materials important to major industries or to a nation's security. By the late 1960's, however, concerns about the world's growing human population, the finite nature of many "nonrenewable" resources, and the environmental and ecological ramifications of resource exploitation had taken hold. Viewed in a global context, resource issues rapidly became more complex. Today, it's nearly impossible to discuss natural resources, sustainable development, renewable resources, ecological resources, or energy resources without it being a global conversation. The way we view our resources and their integration into a global marketplace and worldwide environmental concerns has prompted this third edition of the *Encyclopedia of Global Resources.*

Contents and Scope of Coverage

Salem Press's *Encyclopedia of Global Resources* provides a wide variety of perspectives on both traditional and contemporary views of Earth's resources. In this sense, *Encyclopedia of Global Resources* serves as a bridge connecting the domains of resource exploitation, environmentalism, ecology, geology, and biology, and explains their interrelationships in terms that students and other non-specialists can understand. The 586 alphabetically arranged articles in *Encyclopedia of Global Resources* are as broad as "Agricultural products" and as specific as "Svalbard Global Seed Vault." They range in length from 500 words to more than 3,000 words, and cover topics as diverse as soil, fisheries, forests, aluminum, the Industrial Revolution, the U.S. Department of the Interior, the hydrologic cycle, glass, and placer mineral deposits.

The following categories are also well represented: top resources; specific countries; ecological resources; environment, conservation, and resource management; geological processes and formations; government and resources; historical events and movements; laws and conventions; obtaining and using resources; organizations, agencies, and programs; people; pollution and waste disposal; products from resources; scientific disciplines; and social, economic, and political issues.

In the traditional view of natural resources, the core of the set is a series of more than one hundred articles on specific mineral and other nonliving resources, from aluminum to zirconium. These articles begin with immediately accessible, informative subheads—"Where Found," "Primary Uses," "Technical Definition"—and continue with subsections that address "Description, Distribution, and Forms," "History," "Obtaining," and "Uses."

There are also survey articles on such resource categories as abrasives, gems, radioactive isotopes, and silicates as well as on the geologic processes and formations that produce mineral resources. Reflecting the overwhelming importance of petroleum products to the world, a cluster of articles discuss the chemistry, distribution, and formation of oil and natural gas in addition to oil exploration and drilling, the oil industry, oil shale and tar sands, and petrochemical products. Other energy resources, such as hydroenergy, nuclear energy, solar energy, and wind energy, are also covered in detail. Two other broad resource areas are discussed in a number of articles: plant and animal resources, and ecological resources, such as Earth's atmosphere, biodiversity, forests, medicinal plants, oceans, water, and even resources deriving from extraterrestrial exploration of our solar system. Articles on the former range from specific crops, such as corn, to overviews of animal breeding, agricultural products, and carbon. Articles on the latter reflect the realization that, in an increasingly populated world, natural systems such as rain forests, grasslands, lakes, and wetlands—from their genetic diversity to the global biosphere itself—must be considered crucially important resources, subject to threat and in continual need of being monitored and protected.

Because "natural resources" comprises materials useful or necessary to people, this work includes entries on many aspects of the human dimension of resource exploitation, such as how various resources are obtained and processed. Also discussed are the major secondary or intermediate materials that resources are used to produce, including Carbon fiber and carbon nano-tubes, Cement and concrete, Fiberglass, Gasoline and other petroleum fuels, and Semiconductors. Economic, political, and societal ramifications of resource use are discussed in essays on energy economics and politics, the early history of mineral resource use, resource exploitation and health, and resource use in developing countries. A number of articles stress the environmental effects of human activities related to obtaining and using resources— air and water pollution, mining wastes, deforestation, desertification—as well as phenomena that can be either natural or caused by humans, such as droughts, erosion, and fires. Other articles delineate the issues and choices surrounding resource management, recycling, conservation, sustainable development, preservation, environmentalism, and waste disposal. Another set of essays cover particularly significant pieces of legislation, international conventions, and activities of specific government agencies. Brief articles highlight organizations, historical events, and personages important in the history of resource exploitation, conservation, and environmental protection. Finally, several overviews of important fields of study—from agronomy to geographic information systems to risk assessment—round out the set.

Reference Features

Each article in *Encyclopedia of Global Resources* is signed, and each has summary information at the beginning and cross-references to other articles in the set at the end. All articles are organized using internal subheads, consistent by type of article, and articles that are 1,000 words in length or longer conclude with bibliographies. Many essays also contain sections that direct users to authoritative Web sites, and illustrations have been updated or replaced.

A useful reference feature at the beginning of each volume is a Complete List of Contents, and at the end of volume 4 are several appendixes: an Alphabetical Table of the Elements, the Periodic Table of the Elements, lists of Major U.S. Mineral Resources, Major U.S. Mineral Resources by State, Major Canadian Mineral Resource Production and Values, Major Worldwide Mineral Resources and Producers, Major Worldwide Resources by Country, a Time Line, a Glossary, a Bibliography, and a list of Web Sites. Finally, the set ends with a Category Index that groups similar essays, along with a comprehensive Subject Index.

Acknowledgments

Salem Press wishes to acknowledge the editors of the first edition, Mark S. Coyne of the University of Kentucky and Craig W. Allin of Cornell College. Professor Allin was instrumental in creating the third edition and vast expansion of this work, and Marianne Madsen, of University of Utah, served as the editor of this third edition. We also thank the scholars who contributed original essays, updated their previous work, and/or wrote new material for this and previous editions; a list of their names and affiliations appears on the following pages.

Introduction

Our Earth is overflowing with abundant natural resources. From oceans teeming with life to rainforests with plentiful biodiversity to the desert overflowing with wells of stored reserves, we have plenty. However, it is mandatory that we, as human custodians, care for and preserve this richness for ourselves and for generations to come.

Human ingenuity has led the way in helping us use the wealth of resources available to us. Technology has completely changed the way we use many of our resources. Using technological advances, we have found new ways to use assets and new ways to generate resources. We have discovered how to harness the wind, water, and sun to provide clean power.

Technology has also changed the resources we use. Genetically modified organisms (GMOs), such as rice that has been genetically engineered to incorporate essential vitamins and crops with changes to DNA that make them pest-resistant, have changed the food we eat. We have even created genetically modified bacteria to "eat" oil spills. The human mind continues to expand on and modify the resources we have and the way we use them.

Social media has affected the way we talk about and understand our resource use. News feeds, Facebook, Twitter, and Instagram inform us immediately when major environmental disasters occur, and we can virtually rally around those who protest governmental policies that affect our resources.

These third edition volumes discuss many aspects of the resources of our Earth. They cover the origin and uses of many of the materials that come from the earth such as water, food, and minerals. You will find information on best uses of these resources, and ways that extracting and preserving them have changed. Information on how political and other public figures have changed our world is included. Governmental policies and laws as well as national and international committees on resource use are described in detail. New information has been added about the most important changes relating to our Earth and its resources.

As Wendell Berry said, "The Earth is what we all have in common." By educating ourselves on the resources available and ways to keep this wealth of resources safe and healthy, for the Earth, for us, and for the future, we can all use the Earth's resources effectively and efficiently.

Marianne Moss Madsen, MS
University of Utah

List of Contributors

McCrea Adams
Independent Scholar

Bland Addison
Worcester Polytechnic Institute

Richard Adler
University of Michigan—Dearborn

Steve K. Alexander
University of Mary Hardin-Baylor

Craig W. Allin
Cornell College

Emily Alward
College of Southern Nevada

S. Ashok
Penn State University

Anita Baker-Blocker
Ann Arbor, Michigan

Grace A. Banks
Chestnut Hill College

Joshua I. Barrett
Charleston, West Virginia

Melissa A. Barton
Westminster, Colorado

Harlan H. Bengtson
Southern Illinois University, Edwardsville

Alvin K. Benson
Utah Valley University

John L. Berkley
SUNY, College at Fredonia

Milton Berman
University of Rochester

David M. Best
Northern Arizona University

Cynthia A. Bily
Adrian, Michigan

Margaret F. Boorstein
C. W. Post College of Long Island University

Richard G. Botzler
Humboldt State University

Lakhdar Boukerrou
Florida Atlantic University

Judith J. Bradshaw-Rouse
University of Wisconsin—Madison

Howard Bromberg
University of Michigan

JoEllen Broome
Georgia Southern University

Kenneth H. Brown
Northwestern Oklahoma State University

Jeffrey C. Brunskill
Bloomsburg University of Pennsylvania

Michael H. Burchett
Limestone College

Henry Campa III
Michigan State University

Gary A. Campbell
Michigan Technological University

Jennifer L. Campbell
Lycoming College

Byron D. Cannon
University of Utah

Roger V. Carlson
Jet Propulsion Laboratory

Robert E. Carver
University of Georgia

Dennis W. Cheek
Ewing Marion Kauffman Foundation

Kerry L. Cheesman
Capital University

Judy Arlis Chesen
Capital University

Jill A. Cooper
Boise, Idaho

Robert G. Corbett
Illinois State University

Charles V. Cordaro
Pasadena, California

Mark S. Coyne
University of Kentucky

Alan K. Craig
Florida Atlantic University

James R. Craig
Virginia Polytechnic Institute & State University

Richard A. Crooker
Kutztown University

Robert L. Cullers
Kansas State University

Alan C. Czarnetzki
University of Northern Iowa

Pat Dasch
National Space Society

Jennifer Davis
Kettering, Ohio

LeAnna DeAngelo
Arizona State University

René A. De Hon
University of Louisiana at Monroe

Joseph Dewey
University of Pittsburgh—Johnstown

Albert B. Dickas
University of Wisconsin

John R. Dickel
University of Illinois

David M. Diggs
Central Missouri State University

Steven L. Driever
University of Missouri—Kansas City

Colleen M. Driscoll
Villanova University

Thomas A. Eddy
Emporia State University

H. J. Eisenman
University of Missouri—Rolla

Jessica O. Ellison
Clarkson University

Robert D. Engelken
Arkansas State University

Victoria Erhart
Strayer University

Thomas R. Feller
Nashville, Tennessee

Mary C. Fields
Medical University of South Carolina

David G. Fisher
Lycoming College

Dale L. Flesher
University of Mississippi

Richard H. Fluegeman, Jr.
Ball State University

George J. Flynn
SUNY—Plattsburgh

James F. Fowler
State Fair Community College

Donald R. Franceschetti
University of Memphis

Yongli Gao
East Tennessee State University

June Lundy Gastón
City University of New York

Michael Getzner
Klagenfurt University

Soraya Ghayourmanesh
Bayside, New York

Lenela Glass-Godwin
Texas A&M University
Auburn University

James S. Godde
Monmouth College

Joelle D. Godwin
Eckerd College

Pamela J. W. Gore
Georgia Perimeter College

D. R. Gossett
Louisiana State University—Shreveport

D. Yogi Goswami
University of Florida

Jerry E. Green
Miami University

Richard Wayne Griffin
Prairie View A&M University

Clayton D. Harris
Middle Tennessee State University

Jasper L. Harris
North Carolina Central University

C. Alton Hassell
Baylor University

Craig Bond Hatfield
The University of Toledo

Robert M. Hawthorne, Jr.
Marlboro, Vermont

Charles D. Haynes
University of Alabama

Mark C. Herman
Edison State College

Stephen C. Hildreth, Jr.
Pickens, South Carolina

Robert M. Hordon
Rutgers University

Raymond Pierre Hylton
Virginia Union University

Domingo M. Jariel
Louisiana State University at Eunice

Albert C. Jensen
Central Florida Community College

Richard C. Jones
Texas Woman's University

Chand K. Jotshi
University of Florida

Karen N. Kähler
Pasadena, California

Mark Kanazawa
Carleton College

Kyle L. Kayler
Mahopac, New York

Diann S. Kiesel
University of Wisconsin Center—Baraboo, Sauk County

Grove Koger
Boise State University

Narayanan M. Komerath
Georgia Institute of Technology

Padma P. Komerath
SCV, Inc.

Ludwik Kowalski
Montclair State University

Craig B. Lagrone
O.I. Analytical, CMS Field Products

Ralph L. Langenheim, Jr.
University of Illinois—Urbana

Eugene Larson
Los Angeles Pierce College

Vincent M. D. Lopez
Independent Scholar

Chungu Lu
NOAA Earth System Research Laboratory

R. C. Lutz
CII Group

Fai Ma
University of California, Berkeley

Roxanne McDonald
Wilmot, New Hampshire

Thomas R. MacDonald
University of San Francisco

Elizabeth A. Machunis-Masuoka
Midwestern State University

Marianne M. Madsen
University of Utah

Nancy Farm Männikkö
Centers for Disease Control & Prevention

A. M. Mannion
University of Reading

Sergei A. Markov
Austin Peay State University

W. J. Maunder
Tauranga, New Zealand

Raymond F. Mikesell
University of Oregon

Marian A. L. Miller
University of Akron

Randall L. Milstein
Oregon State University

Alice Myers
Bard College at Simon's Rock

John E. Myers
Bard College at Simon's Rock

Mysore Narayanan
Miami University

Terrence R. Nathan
University of California, Davis

Brian J. Nichelson
Pearland, Texas

Emmanuel U. Nzewi
North Carolina A&T State University

Oghenekome U. Onokpise
Florida A&M University

Robert J. Paradowski
Rochester Institute of Technology

John R. Phillips
Purdue University Calumet

Rex D. Pieper
New Mexico State University

George R. Plitnik
Frostburg State University

Aaron S. Pollak
Omaha, Nebraska

Oliver B. Pollak
University of Nebraska at Omaha
Pollak and Hicks

Victoria Price
Lamar University

Cynthia F. Racer
New York Academy of Sciences, Society for Public Health Education

Steven J. Ramold
Eastern Michigan University

William O. Rasmussen
University of Arizona

Donald F. Reaser
The University of Texas at Arlington

David D. Reed
Michigan Technological University

Edward A. Riedinger
Ohio State University

Gina M. Robertiello
Felician College

Raymond U. Roberts
Oklahoma Department of Environmental Quality

Gene D. Robinson
James Madison University

James L. Robinson
University of Illinois at Urbana-Champaign

Charles W. Rogers
Southwestern Oklahoma State University

Carol A. Rolf
Rivier College

Kathryn L. Rowberg
Purdue University Calumet

Joseph R. Rudolph, Jr.
Towson University

Michael K. Rulison
Oglethorpe University

Neil E. Salisbury
University of Oklahoma

Panagiotis D. Scarlatos
Florida Atlantic University

Elizabeth D. Schafer
Loachapoka, Alabama

Harold H. Schobert
Penn State University

John Richard Schrock
Emporia State University

Steven C. Schulte
Mesa State College

Leslie J. Schwartz
St. John Fisher College

Rose Secrest
Chattanooga, Tennessee

Ronald John Shadbegian
University of Massachusetts—Dartmouth

S. A. Sherif
University of Florida

R. Baird Shuman
University of Illinois at Urbana-Champaign

Carlos Nunes Silva
University of Lisbon

Paul P. Sipiera
William Rainey Harper College

Amy Sisson
Houston Community College

Roger Smith
Portland, Oregon

Robert J. Stern
University of Texas at Dallas

Joan C. Stevenson
Western Washington University

C. J. Stewart
Mote Marine Laboratory

Dion C. Stewart
Georgia Perimeter College

Robert J. Stewart
California Maritime Academy

William H. Stewart
University of Alabama

Theresa L. Stowell
Adrian College

Frederick M. Surowiec
Independent Scholar

Jacqueline Vaughn Switzer
Northern Arizona University

Glenn L. Swygart
Tennessee Temple University

Katrina Taylor
Northern Arizona University

John M. Theilmann
Converse College

Nicholas C. Thomas
Auburn University at Montgomery

Donald J. Thompson
California University of Pennsylvania

Leslie V. Tischauser
Prairie State College

Roger Dale Trexler
Southern Illinois University

Sarah A. Vordtriede
St. Ambrose University

William T. Walker
Chestnut Hill College

C. J. Walsh
Mote Marine Laboratory

Xingwu Wang
Alfred University

William J. Wasserman
Seattle Central Community College

John P. Watkins
Westminster College

Kevin D. Weakley
Western Michigan University

Shawncey Webb
Taylor University

Thomas W. Weber
SUNY at Buffalo

Robert J. Wells
Society for Technical Communication

Kristopher D. White
Kazakhstan Institute of Management, Economics, & Strategic Research

Edwin G. Wiggins
Webb Institute

Thomas A. Wikle
Oklahoma State University

Sam Wong
University of Leeds

William C. Wood
James Madison University

Lisa A. Wroble
Hodges University

Jay R. Yett
Orange Coast College

Ming Y. Zheng
Gordon College

Tom L. Zimmerman
The Ohio State University

■ Common Units of Measure

Common prefixes for metric units—which may apply in more cases than shown below—include *giga-* (1 billion times the unit), *mega-* (one million times), *kilo-* (1,000 times), *hecto-* (100 times), *deka-* (10 times), *deci-* (0.1 times, or one tenth), *centi-* (0.01, or one hundredth), *milli-* (0.001, or one thousandth), and *micro-* (0.0001, or one millionth).

Unit	Quantity	Symbol	Equivalents
Acre	Area	ac	43,560 square feet 4,840 square yards 0.405 hectare
Ampere	Electric current	A *or* amp	1.00016502722949 international ampere 0.1 biot *or* abampere
Angstrom	Length	Å	0.1 nanometer 0.0000001 millimeter 0.000000004 inch
Astronomical unit	Length	AU	92,955,807 miles 149,597,871 kilometers (mean Earth-Sun distance)
Barn	Area	b	10^{-28} meters squared (approx. cross-sectional area of 1 uranium nucleus)
Barrel (dry, for most produce)	Volume/capacity	bbl	7,056 cubic inches; 105 dry quarts; 3.281 bushels, struck measure
Barrel (liquid)	Volume/capacity	bbl	31 to 42 gallons
British thermal unit	Energy	Btu	1055.05585262 joule
Bushel (U.S., heaped)	Volume/capacity	bsh *or* bu	2,747.715 cubic inches 1.278 bushels, struck measure
Bushel (U.S., struck measure)	Volume/capacity	bsh *or* bu	2,150.42 cubic inches 35.238 liters
Candela	Luminous intensity	cd	1.09 hefner candle
Celsius	Temperature	C	1° centigrade
Centigram	Mass/weight	cg	0.15 grain

A

Abrasives

CATEGORY: Mineral and other nonliving resources

Abrasives comprise a large number of both naturally occurring minerals and rocks and manufactured products. In many cases these manufactured products have largely replaced their natural counterparts. Some, such as diamond, are rare; others, including sand and sandstone, are found abundantly in nature. All find uses in the home or in industry because of their characteristic hardness.

Background

Because the abrasives category encompasses a great variety of materials, their worldwide distributions are highly varied. Some, such as garnet and emery, are obtained from only a few localities. Others, such as sand and sandstone, are found on all continents, in all geologic settings, and in rocks representing all geologic ages.

Use of all the abrasives reflects in some manner the characteristics of hardness. That property is utilized in cutting and drilling tools, surface polishing materials, and blasting media. The largest user of abrasives is the automobile industry. Abrasives, both natural and synthetic, are used to perform one of four basic functions: the removal of foreign substances from surfaces ("dressing"), cutting, drilling, and comminution (or pulverizing) of materials. Most abrasives lie toward the upper end of the Mohs hardness scale. With respect to one another, however, they can be categorized as hard, moderate (or "siliceous"), or soft.

Hard Abrasives

The hard abrasives are diamond, corundum, emery, and garnet. Diamond, the hardest naturally occurring substance (10 on the Mohs scale), is normally used in three size categories: stone, bort, and powder. Only a small fraction of the diamond stones produced by mining are of gem quality. All others, as well as those produced synthetically (together referred to as industrial diamonds), are used in various industrial applications, including diamond saws, rock-drilling bits, and other abrasive tools. Bort consists of fragments and small, flawed stones. Most bort, as well as synthetic diamond, is crushed to powder and mixed with water or oil to form a slurry that is used to polish gems. The United States has no exploitable diamond deposits, but it is the world's leading producer of diamond dust, easily satisfying its industrial needs.

Corundum, the second-hardest naturally occurring substance (9 on the Mohs scale), is used principally in crushed form for the polishing and finishing of optical lenses and metals. Its abrasive quality is enhanced by the fact that when broken it forms sharp edges. As it wears, it flakes, which produces new edges. Corundum occurs in contact metamorphic rocks, granite pegmatites, and placer deposits. The United States has no significant deposits of corundum.

Emery is a natural mixture of corundum and magnetite, with minor amounts of spinel, hematite, or garnet. Its value as an abrasive is largely a function of the amount of corundum present. In the United States, commercial emery deposits occur near the town of Peekskill, New York, where it is mined from contact metamorphic deposits. Important production also comes from Greece and Turkey. The principal uses of emery are as abrasive sheets, grinding wheels, and nonskid surfaces on stairs and pavements. Both corundum and emery have been replaced in large measure by synthetic alumina (Al_2O_3).

Of the fifteen varieties of garnet that occur in nature, almandite is the one most commonly used as an abrasive. Uses of garnet include sandblasting, finishing hard woods, the hydrojet cutting of rocks, and (in powder form) the finishing of optical lenses. Garnet has been replaced in metalworking by synthetic materials because they can be made harder and less friable. The United States, which possesses the world's largest reserves of garnet (mostly in the Adirondack Mountains), accounts for half of the world's production and is also the world's largest consumer.

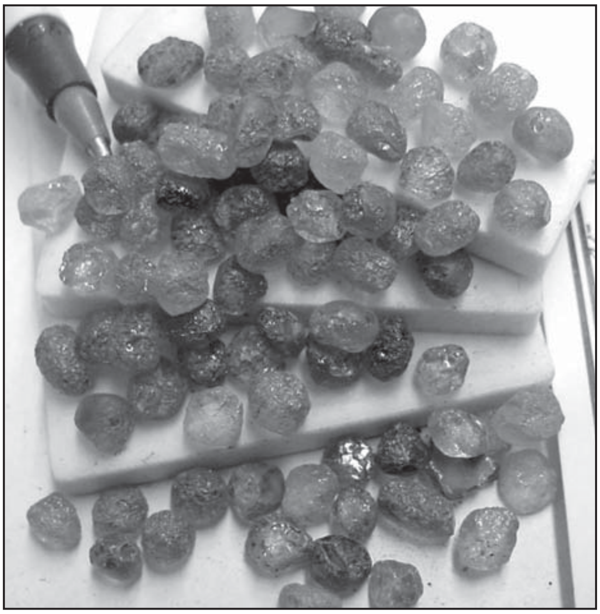
Siliceous Abrasives

The term "silica sand" is taken to mean sand of almost pure quartz content, and sandstone (or quartzite) is the lithified version of that sand. Both are examples of siliceous abrasives of moderate hardness. Silica sand is used for sandblasting and for glass grinding. Historically, sandstone has been shaped into grindstones, whetstones, and millstones. Because high-quality sandstones were deposited in shallow seas during virtually all the geological periods, the reserves of silica sand and sandstone of commercial quality in the United States are enormous. Nevertheless, siliceous material for polishing and pulverizing has been replaced to a large extent by steel balls. The market share of silica sand as a sandblasting medium has declined because of health concerns related to the breathing of silica dust, which can lead to a condition called silicosis.

Other siliceous abrasives include diatomite, pumice, tripoli, flint, and chert. Diatomite, or diatomaceous earth, is an accumulation of the siliceous remains of shell-secreting freshwater and marine algae (diatoms). Because it is lightweight and porous, diatomite finds its most important uses as a filtering medium in water purification and waste treatment plants and as a filler (extender) in paint and paper. As an abrasive it is used in scouring soaps and powders, toothpaste, and metal-polishing pastes. The United States possesses the world's most important reserves of diatomite. Tripoli is the weathering remains of siliceous limestones and is similar to diatomite in composition, characteristics, and uses. Pumice, porous volcanic glass, finds its principal market as building block. A small but significant amount of pumice, however, is used as an abrasive, for scouring and stonewashing. Chert and flint, two of the many varieties of quartz, have been used in pellet form in ball mills for the comminution of metallic ores.

Soft Abrasives

The soft abrasives include feldspar, clay, dolomite, chalk, and talc. They are primarily used for the polishing and buffing of metals. Feldspar, mined from granite pegmatites, is also crushed and used in soaps and scouring powders.



Corundum, pictured, is one of four heavy-abrasive materials. (USGS)

Synthetic Abrasives

Beginning in about 1900, a variety of manufactured abrasives were developed that have gradually replaced natural abrasives in the marketplace. In addition to lower cost, manufactured abrasives have the advantages of being tailored to meet specific industrial needs and of being produced in uniform quality. Among the important manufactured abrasives are synthetic diamond, cubic boron nitride, fused aluminum oxide, silicon carbide, alumina-zirconia oxide, and steel shot and grit. Synthetic diamonds were first produced in 1955, the result of a process that fuses graphite and metallic catalysts at extremely high temperature and pressure. Cubic boron nitride, first synthesized in 1957, is the next hardest substance after diamond and has challenged synthetic diamond as an abrasive in many industrial applications. Fused aluminum oxide is formed at high temperatures in an electric furnace by the fusing of either bauxite or corundum. Uses include tumbling, polishing, and blasting. It is also used in coated abrasives. Silicon carbide is fused from a mixture of quartz sand and coke; it finds its primary uses as a coated abrasive, in polishing and buffing media, and in wire saws for the cutting of stone. One of the primary uses of steel shot and grit is as a blasting medium. The automobile industry is the largest consumer of artificial abrasives, and the economic fortunes of the two industries are closely tied together.

Donald J. Thompson

Further Reading

Giese, Edward, and Thomas Abraham. *New Abrasives and Abrasives Products, Technologies, Markets.* Norwalk, Conn.: Business Communications, 1997.

Hayes, Teresa L., Debra A. Celinski, and Rebecca Friedman. *Abrasives Products and Markets.* Cleveland, Ohio: Freedonia Group, 2000.

Jensen, Mead Leroy, and Alan M. Bateman. *Economic Mineral Deposits.* 3d ed. New York: Wiley, 1979.

Kogel, Jessica Elzea, et al., eds. "Abrasives." In *Industrial Minerals and Rocks: Commodities, Markets, and Uses.* 7th ed. Littleton, Colo.: Society for Mining, Metallurgy, and Exploration, 2006.

Web Site

U.S. Geological Survey

Manufactured Abrasives: Statistics and Information.
http://minerals.usgs.gov/minerals/pubs/commodity/abrasives/index.html#mcs

See also: Corundum and emery; Diamond; Diatomite; Garnet; Igneous processes, rocks, and mineral deposits; Metamorphic processes, rocks, and mineral deposits; Mohs hardness scale; Pegmatites; Placer deposits; Pumice; Quartz; Sand and gravel; Sandstone; Sedimentary processes, rocks, and mineral deposits.

Acid precipitation

Category: Pollution and waste disposal

The existence of acid precipitation became known in the late nineteenth century, but it claimed general attention beginning in the early 1960's. Precipitation whose acidity is greater than that of natural rainwater is termed acid precipitation and is connected to several environmental and health problems.

Background

Natural, uncontaminated precipitation is somewhat acidic because of the interaction of the water droplets with carbon dioxide in the atmosphere. This interaction produces carbonic acid, which is weakly acidic and lowers the pH from neutral (7) to around 5.5. This is not considered acid precipitation, but any samples that show a pH of less than 5 are considered acidic.

Formation of Acid Rain

Three sources of acid precipitation stand out as the major contributors: combustion of coal or other fuels with a high sulfur content, the roasting of some metal sulfide ores, and the operation of internal combustion gasoline engines. In the first two cases the presence of sulfur is the problem. Sulfur, when combined with oxygen during combustion or heating processes, produces sulfur dioxide, which, in the presence of particulate matter in the atmosphere, is further oxidized to sulfur trioxide. This compound, dissolved in water, becomes sulfuric acid. In the internal combustion engine the temperature attained is high enough to allow nitrogen and oxygen, present in ordinary air, to react and form a complex set of nitrogen oxides. These oxides, again when dissolved in water, produce nitrous and nitric acid. Each of these acids contributes to the total acid load and causes a decrease in the pH of all forms of precipitation.

Effects of Acid Precipitation

The environmental effects of acid precipitation depend on the soil on which it falls. For example, soils that are derived from the weathering of limestone have the capability of neutralizing the acidity of the precipitation, while those that have resulted from granite do not. The effects can be seen in aquatic ecosystems, in soils and their vegetative covers, and on materials of construction. Acid precipitation eventually runs off into bodies of water and, in time, can have a major impact on their acidity. Many aquatic species can tolerate only small pH changes in their environment before they are killed, and even smaller changes cause stunting and poor reproduction. Considering plants, some are directly affected by the acidity striking their leaves, while others are negatively affected by aluminum, which they take up from the soil through their roots. Aluminum in soil is usually immobilized as an insoluble material, but

A forest in the Czech Republic showing effects of acid rain. (Lovecz, via Wikimedia Commons)

acidity in the soil moisture dissolves the material and allows the aluminum to migrate to the plants. Limestone has been used as a material for much building construction as well as the material of which many statues and other decorative objects are made. However, the acidity of the precipitation causes limestone to dissolve, and the effect may be seen in the loss of definition in many outdoor monuments. Even the steel that is the backbone of much construction is corroded at a much higher rate in the presence of acids.

There are human health consequences of acid precipitation as well. The presence of fine acid droplets in the air can lead to respiratory tract irritation. For healthy people this is not a serious problem, but it is a problem for those already troubled by asthma, emphysema, or other lung conditions.

Alleviation of Acid Precipitation

Abatement of the problem has been approached from two principal directions. It is possible to remove much of the sulfur from coal or liquid fuels before they are burned and therefore to greatly reduce the production of sulfur oxides. Coal liquefaction or gasification accomplishes this, but at considerable dollar cost. Internal combustion engines can be designed to operate at lower temperatures to lower the emissions of nitrogen oxides, but they are less efficient when so run. In smelting operations the ores can be preconcentrated so that a smaller amount of undesired minerals enters the smelter itself. For example, a mixed iron sulfide/nickel sulfide ore can be concentrated to minimize the iron sulfide content and take mainly the more desired nickel mineral to the smelter.

Once the oxides are formed, they can be removed from the exit gases or they can be subjected to further reaction to change them into compounds with less environmental impact. Sulfur dioxide from roasting can be trapped in the liquid form or can be converted to liquid sulfuric acid and, in each case, sold as a by-product. The sulfur dioxide in the exhaust from burning is not concentrated enough to be treated in this fashion, but it can be removed from the exhaust stream by absorbing it in a limestone slurry for later landfill disposal. The current answer for the nitrogen oxide emissions is treatment with a catalytic converter in the exhaust line of the engine. The catalyst converts the oxides back to elemental nitrogen and water at about 80 percent efficiency.

Kenneth H. Brown

Further Reading

Bunce, Nigel J. "Acid Rain." In *Introduction to Environmental Chemistry.* 2d ed. Winnipeg, Man.: Wuerz, 1994.

Howells, Gwyneth Parry. *Acid Rain and Acid Waters.* 2d ed. New York: E. Horwood, 1995.

Johnson, Russell W., et al., eds. *The Chemistry of Acid Rain: Sources and Atmospheric Processes.* Washington, D.C.: American Chemical Society, 1987.

Legge, Allan H., and Sagar V. Krupa, eds. *Air Pollutants and Their Effects on the Terrestrial Ecosystem.* New York: Wiley, 1986.

McCormick, John. *Acid Earth: The Politics of Acid Pollution.* 3d ed. London: Earthscan, 1997.

Manahan, Stanley E. *Environmental Chemistry.* 8th ed. Boca Raton, Fla.: CRC Press, 2005.

Somerville, Richard C. J. "Air Pollution and Acid Rain." In *The Forgiving Air: Understanding Environmental Change.* 2d ed. Boston: American Meteorological Society, 2008.

Visgilio, Gerald R., and Diana M. Whitelaw, eds. *Acid in the Environment: Lessons Learned and Future Prospects.* New York: Springer, 2007.

Whelpdale, D. M., and M. S. Kaiser, eds. *Global Acid Deposition Assessment.* Geneva, Switzerland: World Meteorological Organization, Global Atmosphere Watch, 1997.

Web Sites

Environment Canada
Acid Rain
http://www.ec.gc.ca/acidrain

U.S. Environmental Protection Agency
Acid Rain
http://www.epa.gov/acidrain

U.S. Geological Survey
Acid Rain, Atmospheric Deposition, and Precipitation Chemistry
http://bqs.usgs.gov/acidrain/new/frontpage_home.htm

See also: Air pollution and air pollution control; Atmosphere; Coal gasification and liquefaction; Hydrology and the hydrologic cycle; Internal combustion engine; Metals and metallurgy; Nitrogen cycle; Sulfur cycle.

Aerial photography

Category: Obtaining and using resources

Aerial photography, which dates to the nineteenth century, has enabled scientists to quantify and predict changes in land use, soil erosion, agricultural development, water resources, habitat, vegetation distribution, animal and human populations, and ecosystems. Aerial photography also is used to construct thematic maps that show the distribution of a variety of global resources.

Definition

Aerial photography is a form of remote sensing that relies on film or digital capture to acquire information about Earth's surface from elevated platforms. These platforms include balloons, airplanes, and satellites. The primary advantage of aerial photography over ground-based observations is the elevated vantage point, which can provide images covering vast expanses of Earth's surface.

Overview

The invention of photography was announced in 1839 at the joint meeting of the Academies of Sciences and Fine Arts in Paris, France. Nineteen years later, in 1858, Gaspard-Nadar Félix Tournachon made the first aerial photograph from a tethered balloon over Val de Bièvre, France. The oldest extant aerial photograph dates to 1860, when James Wallace Black photographed Boston, Massachusetts, from a balloon tethered above Boston Common. The first aerial photograph made from an airplane was in 1908; the first aerial photograph made from a satellite was in 1959. In the twenty-first century, aerial photography is a vital tool for documenting and managing Earth's resources.

In order to obtain quantitative information about the Earth's resources from an aerial photograph, methods must be applied to the photograph that allow for reliable estimates of spatial relationships. Obtaining such relationships falls under the broad field of photogrammetry. By applying photogrammetric methods, analysts can relate distances on the photograph to distances on the ground. Object heights and terrain elevations can be obtained by comparing photographs made from two different vantage points, each with a different line of sight. This method is based on the principle of parallax, wherein the apparent change in relative position of stationary objects is compared between the photographs. Additional information can be gleaned from aerial photographs by examining tonal changes and

Aerial shot of Qingdao Cangma Mountain Development, Qingdao, China. (MCM Group International, via Wikimedia Commons) shadow distributions within the photograph. Tonal changes can provide information on texture, which can be used to distinguish between vegetation type, soil type, and other surface features. Because the shapes of shadows change with time of day and are unique to particular objects, such as bridges, trees, and buildings, the shadows can be used to aid in the identification of the objects. Because film can record wavelengths of radiation that are invisible to the eye, such as thermal infrared radiation, features such as plant canopy temperature can be measured and displayed on an aerial photograph.

Aerial photography has many applications, including geologic and soil mapping, agricultural crop management, forest monitoring and management, rangeland management, water pollution detection, water resource management, and urban and regional planning. In geologic mapping, for example, aerial photography can be used to identify faults and fractures in Earth's surface as well as rock and soil types. By comparing these features over time, scientists can make inferences about the forcing agents, such as wind and water, that have shaped the land. As world population grows and demand for global resources increases, aerial photography will continue to be an important tool for guiding global resource management.

Terrence R. Nathan

SEE ALSO: Conservation; Environmental engineering; Geology; Irrigation; Land management; Land-use planning; Rain forests; U.S. Geological Survey; Wind energy.

Agenda 21

CATEGORY: Laws and conventions
DATE: Adopted June 1992

Agenda 21 is the action plan of the United Nations for the promotion of sustainable development in the twenty-first century.

A Global Partnership

The opening paragraph of the Preamble to Agenda 21 presents an unusually stark statement of the challenges facing humanity at the beginning of the twenty-first century and the need for international cooperation to meet those challenges.

Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our wellbeing. However, integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems, and a safer, more prosperous future. No nation can achieve this on its own; but together we can—in a global partnership for sustainable development.

Background

Agenda 21 was approved in the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, from June 3 to 14, 1992, when more than one hundred heads of state met in the first Earth Summit. Sustainable development means that which "meets the needs of the present, without compromising the capacity of future generations to meet their own needs." This concept was first mentioned in the 1980 report *World Conservation Strategy*, published by the International Union for Conservation of Nature (IUCN), and defined, in 1987, in the Brundtland Report (*Our Common Future*), prepared by the U.N. World Commission on Environment and Development, created in 1983 and chaired by Gro Harlem Brundtland. The council has met several times since the original 1992 summit. In 1997, 2002, and 2012, leaders met at events such as the World Public Meeting on Culture to reaffirm and renew Agenda 21's goals and guidelines.

Agenda 21 provided the framework for the United Nations to later create the Millennium Declaration and, subsequently, the Millennium Development Goals. These objectives were meant to guide progress from 1990 to 2015. As the previous provisions were ending, the Sustainable Development Goals, or the 2030 Agenda, was proposed, negotiated, and ratified. While Agenda 21 outlines methods and proposes agreements in order to improve global conditions, the 2030 Agenda lays out overarching objectives for international relations and societal conditions.

The 2030 Agenda

In September of 2015, the United Nations General Assembly adopted Resolution A/RES/70/1, entitled "Transforming our world: the 2030 Agenda for Sustainable Development." The adoption of this resolution was unanimous, with some citing the foundational financial work of the Addis Ababa Action Agenda as a motivational factor. The agendas, developed in tandem but implemented on different schedules, have formal links to one another and similar objectives.

The 2030 Agenda is focused on the improvement of global conditions through the alteration of structural forces which perpetuate inequality, poverty, and instability. In response to criticism of the Millennium Developmental Goals, SDGs attempt to address the system which allows these problems, rather than short-term improvements on expanding issues. Questions have been raised about the contradictions between goals—for instance, a construction project which works toward Goal 9: Industry, Innovation, and Infrastructure might have negative effects on the environment at large (Goals 7, 12, 13, 14, & 15) or, after construction has finished, the resultant business may affect inequality and the cost of living in an economy.

Because this agreement is non-binding, global participation has not been consistent. For instance, the Council of Baltic Sea States has created the Baltic 2030 Action Plan to implement local changes. Because of specialized regional economies, the SDGs must be handled differently in order to achieve lasting improvement. The results of this coalition are clear—member states such as Sweden, Denmark, Finland, and Germany held the top four spots on the 2018 SDG index ranking. However, even of those top-performing countries, only Sweden and Denmark fulfilled their spending commitment to Official Development Assistance. The United States was given a score of 0 when surveyed regarding implementation of SDGs in 2018, as well as a "critically insufficient" rating on efforts to combat climate change.

Though many countries are working to meet these goals and improve conditions for their citizens, experts fear it may not be enough to meet their original objectives. Statistics for child malnutrition and starvation are improving, but to eradicate hunger and poverty, the agenda should be adhered to wholeheartedly and by all signatory states. Ambitious goals and tight timelines call the efficacy of the agenda into question, with some asking what the United Nations' contingency plan would be if the goals were not met by 2030. Ban Ki-moon, the sitting United Nations Secretary-General, gave the following justification: "We don't have plan B because there is no Planet B!"

Provisions

The Earth Summit adopted key documents such as the Rio Declaration on Environment and Development, the Statement of Principles for the Sustainable Management of Forests, the Convention on Climate Change, the Convention on Biological Diversity, and Agenda 21–the global plan of action on sustainable development. The monitoring of these agreements is conducted by the U.N. Commission on Sustainable Development.

Agenda 21 is a global partnership promoted by the United Nations, based on the principle that it is necessary to meet equitably the needs of present and future generations and on the idea of the indivisibility of environmental protection and economic and social development. Agenda 21 calls for ensuring the sustainable development of the environment through social and economic programs, through protection and conservation of national resources, by enabling major government and civilian groups, and by embracing education, technology, and innovation.

After 1992, the United Nations reaffirmed on several occasions that Agenda 21 remained the main program of action for achieving sustainable development, and programs for the further implementation of Agenda 21 were also adopted. In 2002, the World Summit on Sustainable Development, held in Johannesburg, South Africa, through the Johannesburg Plan of Implementation, strongly reaffirmed the U.N. commitment to the Rio principles and to the full implementation of Agenda 21 and the development goals contained in the 2000 U.N. Millennium Declaration. In 2009, the financial crisis and the global economic recession coupled with the food, energy, and climate crisis made more explicit the need for global and local approaches to sustainable development.

Chapter 28 of Agenda 21 calls for local authorities to develop their own local version of the agenda. Local Agenda 21 includes the preparation and implementation of a long-term strategic action plan for sustainable development. It is a participative, multisector, and multistakeholder process and aims to locally fulfill the objectives of Agenda 21. It is a process in which local governments, citizens, professionals, entrepreneurs, and organizations from the civil society work together to define priorities for local sustainable development in environmental, social, and economic areas. Organizations and networks of local governments have been active in the implementation of Local Agenda 21 in all continents, with such groups as the International Council for Local Environmental Initiatives, an international association of local governments for sustainability; and the movement of European Cities and Towns for Sustainable Development, exemplified by the 1994 Aalborg Charter, the 2004 Aalborg Commitments, and the 2007 Spirit of Seville declaration.

Impact on Resource Use

In 1997, the United Nations made a five-year review of Agenda 21 and reported its findings in a resolution adopted by the General Assembly (Programme for the Further Implementation of Agenda 21). In this review, the United Nations recognized that a number of positive results had been achieved but the overall trends were considered to be worse than in 1992. Among the results the United Nations considered positive were that 150 countries had established national-level commissions or other forms of coordination designed to implement sustainable development strategies; the efforts of local authorities in the implementation of Local Agenda 21; the role of nongovernmental organizations, the scientific community, and the media in the rise of public awareness of the relationship between the environment and development; and the development of green businesses in all sectors of the economy.

Other positive developments in the implementation of Agenda 21 included the adoption of the U.N. Framework Convention on Climate Change, the Convention on Biological Diversity, the Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, and a series of agreements and conventions related to the sea and the marine environment. Progress was made through the implementation, in national and international legislation, of key principles included in the Rio Declaration on Environment and Development, such as the precautionary principle, the principle of common but differentiated responsibilities, the polluter-pays principle, and the environmental impact assessment principle.

Carlos Nunes Silva

Further Reading:

Ban Ki-moon. "Remarks to the Press at COP22."Sustainable Development Goals- United Nations, 15 Nov. 2016, www.un.org/sustainabledevelopment/blog/2016/11/secretary-generals-remarks-to-the-press-at-cop22/.

Aggregates

Category: Mineral and other nonliving resources

Production of rock and crushed stone is an "invisible" industry, one that exists almost everywhere but goes largely unnoticed. Only when the products of this industry are needed or when producers are in conflict with environmental or regulatory agencies is their existence given much attention. Stone and rock are available and used worldwide, primarily in the construction industry.

Background

The crushed stone and rock industry has been in existence since time immemorial. Ancient roads throughout the world were paved with stone that was either found in the desired size or crushed by animal or human power and sized with crude sieves. As the construction industry became more sophisticated and exacting, so did requirements for engineered building products. Today the engineered aspects of manufactured stone products extend not only to physical dimensions but also to the chemical quality of the products.

The term "aggregate" represents all types of crushed stone and rock, from sand and gravel to