CIRCUM-PACIFIC MAP SERIES
MAP CP-44
Explanatory pamphlet accompanies map

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

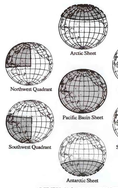
CIRCUM-PACIFIC MAPS

This map is one in a series of maps covering the Pacific, Antarctic, and Arctic regions. The maps have been compiled as part of the Circum-Pacific Map Project, a cooperative international effort to show the relation of mineral and energy resources to the tectonic framework of the geologic environment. The project was one of the activities of the Circum-Pacific Council for Energy and Mineral Resources.

The Map Project is made up of six panels of Earth scientists from countries in the Pacific region who contribute to maps of the Northwest, Northeast, Southwest, Southeast Quadrants, the Arctic and Antarctic areas. Eight series of maps are already published or are being prepared for final publication: Geographic, Base, Plate-Tectonic, Geodynamic, Geologic, Tectonic, Mineral-Resources, and Energy-Resources.

The six overlapping maps cover the Pacific Basin at a scale of 1:10 million, and a seventh map covers the entire region at a scale of 1:17 million. All are plotted on the Lambert azimuthal equal-area projection. The index map shows the boundaries of the quadrant maps and the boundaries of the Arctic and Antarctic Sheets in the Pacific Ocean.

Geographic names are as recommended by the U.S. Board on Geographic Names, taking into account the recommendations of the Circum-Pacific Map Project panels. Names and boundaries on the maps do not necessarily reflect recognition of the political status of an area by those involved in the preparation and publication of these maps.

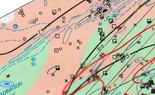


INDEX TO MAP SHEETS

MINERAL-RESOURCES MAP SERIES

Maps of the Mineral-Resources Series show both land-based and seafloor deposits and resources of metallic and some nonmetallic minerals. Land-based deposits are shown without regard to their status of exploitation: thus, some have been largely or entirely mined out, but they are included as indicative of where elements have been concentrated by geologic processes to form ores in the past and thus may suggest favorable area for exploration.

Only nearshore marine deposits have been exploited to date; most are concentrations of heavy minerals derived by erosion and transportation of onshore materials to the coastal zone. Known deep-sea mineral resources shown on the map consist of (1) widespread ferromanganese oxide nodules are crusts that contain cobalt, copper, nickel, and other metals; (2) phosphorite nodules containing trace metals; (3) deposits of zinc, copper, and other metallic sulfides that form by hydrothermal activity along active spreading ridges (and possibly elsewhere); and (3) accumulations of phosphorite-bearing crusts, nodules, and finer grained material on the sea floor or in near-bottom sediments.



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MINERAL-RESOURCES MAP OF THE CIRCUM-PACIFIC REGION
SOUTHEAST QUADRANT

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MAP PRODUCTION BY U.S. GEOLOGICAL SURVEY
Compilation coordinated by George Gryc
Cartography by Frank J. Sidlauskas, Jr. and Theresa R. Swint-Iki

SCALE : 1:10,000,000

250 0 250 500 750 1000 1250 1500 KILOMETERS
250 0 250 500 750 MILES
200 0 200 400 600 NAUTICAL MILES

Lambert Azimuthal Equal-Area Projection
(Map Center Point: 40° S., 100° W.)

1996

SOURCES OF DATA

LAND RESOURCES
The principal data sources are the metallogenic and minerals maps of: Venezuela (Bellizzia and others, 1980; Martín, 1976), Colombia (Barrero, 1976), Ecuador (Paladines, 1980), Peru (Bellido and others, 1972), Bolivia (Ahlfeld, 1954; Claure and Minaya, 1979), Argentina (Angelelli and others, 1970), and Chile (Ruiz and others, 1965; Ulriksen, 1990). Other sources were: Carmona (1978), Goossens (1969), Martín (1983), and specially compiled maps by A. Bellizzia, N. Pimentel, C. Martín (Venezuela), H. Duque-Caro (Colombia), G. Resanoff (Ecuador), V.R. Sympson and T. Goosens (Peru), and M. Reinoso (Argentina).

SEAFLOOR RESOURCES
Data were provided by the following organizations: Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany; Commission for Geological Mapping; Prospecting for Mineral Resources in South Pacific Offshore Areas, Geological Survey of Japan; Institut Français de Recherches pour l'Exploitation de la Mer, Lamont-Doherty Earth Observatory, National Oceanic and Atmospheric Administration, Scripps Institution of Oceanography, Smithsonian Institution, and U.S. Naval Electronics Laboratory. H.T. Mullins, California State University, San Jose, R.P. Shaldrick, U.S. Geological Survey, and W.C. Burnett, Florida State University, updated the phosphate data. R.A. Koski, U.S. Geological Survey, provided information on seafloor sulfides and submarine hot springs. The majority of the seafloor compositional data are from the U.S. Geological Survey World Ocean Ferromanganese Crust Database and the Scripps Institution of Oceanography Nodule Data Bank. Evaluation of these data are discussed in Manheim and Lane-Bostwick (1989). Other sources were Ewing and others, (1971), Hutchinson (1950), and Rawson and Ryan (1978).

GEOLOGIC BACKGROUND
Land geology generalized from Corvalán (1985). Seafloor sediment data generalized from McCoy (1985). Active plate boundaries and intraplate structure from Moore (1981).

BASE MAP
Geographic Map of the Circum-Pacific Region, Southeast Quadrant, American Association of Petroleum Geologists, 1977, compiled by the U.S. Geological Survey, Reston, Virginia.

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Rawson, M.S., and Ryan, W.B.F., 1978, Ocean floor sediment and polymetallic nodules: Palisades, New York, Lamont-Doherty Geological Observatory, scale 1:23,230,300.
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EXPLANATION

GEOLOGIC BACKGROUND

CORRELATION DIAGRAM FOR MAP LEGENDS OF THE SOUTHEAST AND ADJOINING QUADRANTS IN THIS SERIES

Ages in million years (Ma) after Sohl and Wright (1980)

Antarctica Sheet	Southeast Quadrant	Northeast Quadrant		Age	Ma
Qa	Q	Q		QUATERNARY	
	Tn	Tn	Cz	Pliocene	2
				Miocene	24
	Tp	Tp		Oligocene	38
				Eocene	55
	Tp	Tp		Paleocene	63
Kn	Kn	Kn		Late Cretaceous	96
Ka	Ka	Ka		Early Cretaceous	138
Js	Js	Js	Mz	Jurassic	205
Jl	Jl	Jl		Late Triassic	
Tr	Tr	Tr		Middle Triassic	
				Early Triassic	~240
				Permian	290
				Late Carboniferous	~320
				Early Carboniferous	360
				Devonian	405
				Silurian	438
			Pz	Ordovician	500
				Cambrian	
				Late Proterozoic	~570
				Middle Proterozoic	900
				Early Proterozoic	1600
PreCambrian			PreCambrian		2500
A					

Land geology—Colors and pattern show the essential nature of the rocks. Geologic ages are indicated, where feasible, by letters keyed to those in the Correlation Diagram

- **Surficial deposits (Quaternary)**
- **Essentially undeformed, principally extrusive volcanic rock (Neogene-Quaternary)**—Felsic (a); intermediate to mafic (b); mafic (c)
- **Basinal and marginal deposits (Tertiary-Cretaceous)**—Marine (a); est continental (b)
- **Deformed sedimentary and volcanic rocks (Mesozoic-early Cenozoic)**
- **Fore-arc, inland arc-marginal basin sequences**—Ophiolite complexes and deep-water marine sequences (a); non-volcanic marine sequences (b)
- **Arc-backarc sequences**—Predominantly volcanogenic units shown by pattern. Intermediate to mafic extrusive (a); mostly marine (b); and mostly continental (c)
- **Unmetamorphosed sedimentary and volcanic rocks (Paleozoic)**
- **Metamorphic complexes (mostly Phanerozoic)**
- **Crystalline rocks (Precambrian)**
- **Felsic to intermediate intrusive igneous rocks (Phanerozoic)**
- **Ultramafic rocks**
- **Contact**
- **Fault**

Seafloor sediment—Character of surficial sediments shown by pattern and(or) color

- **Terrigenous silt/sand/gravel**
- **Clay, pelagic clay**
- **Biosiliceous ooze/clay***
- **Calcareous ooze/clay***
  *Coarser material indicated by stipple pattern

Active plate boundaries—Dashed where inferred

- **Spreading ridge**
- **Transform fault**
- **Subduction zone**—Sawteeth on upper plate

BASE MAP

Bathymetric contours—Depth of water in **meters** shown by 200 m contour and at 100 m intervals from 1000 m depth, intermediate contours dashed.

- **Sabar (salt flats)**
- **Ice shelf**
- **Ice front or edge of ice shelf**
- **City**—1,000,000 or more
- **City**—Less than 1,000,000
- **Station (Antarctica)**
- 4317 **Height in meters**

LAND RESOURCES

Deposit type—Shown by tick(s) on basic symbol

- **Veins and shear-zone fillings**
- **Stratabound, including magmatic cumulates**
- **Stockworks, including "porphyry" deposits**
- **Magmatic and irregular massive deposits**
- **Skarn or greisen deposits**
- **Sandstone (red bed) deposits**
- **Laterite deposits (surficial chemical concentrations)**
- **Placer deposits (surficial mechanical concentrations)**

Age of mineralization—Geologic age of mineralization shown by orientation of double ticks on ocne deposits

1. Paleozoic and(or) older
2. Late Paleozoic-Triassic
3. Triassic
4. Late Jurassic and(or) Early Cretaceous
5. Late Cretaceous
6. Early Tertiary
7. Late Tertiary
8. Post-Tertiary

Commodities—Shown by shape and color of symbol

W	Sn	Be	Mn(Ta)U
Cu(Au,Ag)	Mo	Cu(Ni,Pb,Ag,Au)	Cu(Ni)
Au(Ag)	Ag(Pb)(Cu,Au)	Au(Ag, Ag,Au)	Semi-precious gems
S	FeS	Nitrate	B
Cr	Sb(Hg)	Li	Asbestos
Fe	Zn	B group	Magnesite
Pb	Pb,Zn, Zn(Pb	Gypsum-anhydrite	
Ni	Bi	Na(K,Mg)(Al,Ca)	Sr
U	V	REYs	Al
Ir	Mn	Ti	F*

*Reported occurrence of insular (guano-derived) phosphate indicated by "P"

Deposit size—By size of symbol. Limits in metric tons of metal or mineral contained unless otherwise specified. Past production and(or) reserves listed.

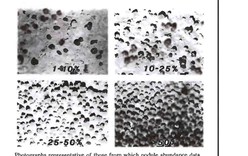
Size	Large	>	Medium	>	Small
Aluminum (bauxite) (Al_2O_3)	100,000,000		1,000,000		
Antimony (Sb)	50,000		5,000		
Asbestos	10,000,000		100,000		
Barite ($BaSO_4$)	5,000,000		50,000		
Beryllium (BeO)	1,000		10		
Bismuth (Bi)	10,000,000		100,000		
Chromium (Cr_2O_3)	5,000,000		10,000		
Cobalt (Co)	20,000		1,000		
Copper (Cu)	1,000,000		50,000		
Fluorite (CaF_2)	5,000,000		50,000		
Gold (Au)	500		25		
Graphite (C)	1,000,000		10,000		
Gypsum-anhydrite ($CaSO_4$)	100,000,000		5,000,000		
Iron (Fe)	100,000,000		5,000,000		
Lead (Pb)	1,000,000		50,000		
Lithium (Li_2O)	100,000		10,000		
Magnesium ($MgCO_3$)	10,000,000		100,000		
Manganese (ore of >40% Mn)	10,000,000		100,000		
Mercury (Hg)	10,000		1,000		
Molybdenum (Mo)	500,000		5,000		
Nickel (Ni)	500,000		25,000		
Niobium-Tantalum (R_2O_5)(Nb-Ta)$_2O_5$	100,000		1,000		
Phosphate (P_2O_5)	200,000,000		200,000		
Platinum group (Pt)	100		1,000		
Potassium (K_2O)	10,000,000		1,000,000		
Precious gems	10		100		
Pyrite (FeS$_2$)	20,000,000		200,000		
Rare earths (R_2O_3)	1,000,000		10,000		
Semi-precious gems	100		1,000		
Silver (Ag)	10,000		500		
Sodium (salts) (Na)	10,000,000		1,000,000		
Sodium (salts) (Sr)	1,000,000		10,000		
Sulfur (S)	10,000,000		100,000		
Thorium (Th)	100,000		1,000		
Tin (Sn)	100,000		5,000		
Titanium (TiO_2)	10,000,000		1,000,000		
Tungsten (W)	10,000		500		
Uranium (U)	10,000		500		
Vanadium (V)	10,000		500		
Zinc (Zn)	1,000,000		50,000		

SEAFLOOR RESOURCES

MANGANESE NODULES

Abundance data—Photograph station showing percent of seafloor covered by nodules

- 0%
- <1%
- 1-10%
- 10-25%
- 25-50%
- >50%



Photographs representative of those from which nodule abundance data were derived. Photographs courtesy of Lamont-Doherty Earth Observatory and Kennecott Explorations, Inc.

Occurrence data—Sediment cores used in conjunction with bottom photographs to estimate seafloor coverage

- × **Nodules recovered**
- ○ **Nodules not recovered**

- **Abundance contours**—In percent. Areas where seafloor coverage is greater than 10 percent are indicated by diagonal ruled pattern. Hachures point toward area of less than 1 percent coverage.

Chemical data—Analytical data from dredge or core samples of nodules or crusts. Data from these points were not used in estimating seafloor coverage

- + **>1.5% nickel plus copper**
- + **1.0-1.5% nickel plus copper**
- **<1.0% nickel plus copper**
- **>1.0% cobalt**
- **>35% manganese**
- Outline of area for which analyses average 1.8 percent or more nickel plus copper

MANGANESE CRUSTS

Cobalt content—In percent. Cobalt data normalized to a hydroxcopic moisture and asbestos- (detrital matter) free basis. The algorithm to obtain these values is given by Co* = Co x 51.23 / (Fe+Mn) (Manheim and Lane-Bostwick, 1989)

- **x <0.5**
- **x 0.5-1.0**
- **x 1.0-1.5**
- **x >1.5**

POLYMETALLIC HYDROTHERMAL DEPOSITS

- **Seafloor sulfide**
- **Sub-seafloor sulfide**—In Deep Sea Drilling Project hole
- **Submarine hot spring**

OTHER SEAFLOOR DEPOSITS

- **Phosphorite**—Reported occurrence on seamount or continental shelf
- **Heavy mineral sand**—Reported occurrence

Base by U.S. Geological Survey, 1978
Modified in 1990

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