USGS science for a changing world

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

CIRCUM-PACIFIC MAP SERIES
MAP CP-46
*Pamphlet accompanies map*

CIRCUM - PACIFIC COUNCIL FOR ENERGY AND MINERAL RESOURCES



# MINERAL-RESOURCES MAP OF THE CIRCUM-PACIFIC REGION

## NORTHWEST QUADRANT

TOMOYUKI MORITANI, CHAIRMAN, NORTHWEST QUADRANT PANEL

**Compilers and Principal Contributors***

**LAND RESOURCES**

Masaharu Kamitani, Geological Survey of Japan, Tsukuba, Ibaraki, 305-8567 Japan
Pow-Foong Fan, Hawaii Institute of Geophysics, Honolulu, Hawaii 96822, USA
Keiichiro Kanehira, Chiba University, Yayoi 1-33, Chiba, 260 Japan
Shuzo Ishihara, Geological Survey of Japan, Tsukuba, Ibaraki 305-8567 Japan
Yoshihiko Shirazaki, Geological Survey of Japan, Tsukuba, Ibaraki, 305-8567 Japan
Katherina Radkevich, Far East Geological Institute, Prospect Stoletia 159, Vladivostok, 690022, USSR
W. David Palfreyman, Australian Geological Survey Organisation, Canberra, A.C.T. 2601.
Sadahisa Sudo, Geological Survey of Japan, Tsukuba, Ibaraki, 305-8567 Japan

**SEAFLOOR RESOURCES**

David Z. Piper, U.S. Geological Survey, Menlo Park, California 94025, USA
Therera R. Swint-Ikl, U.S. Geological Survey, Menlo Park, California 94025, USA
Floyd McCoy , University of Hawaii, Kaneohe, Hawaii 96744, USA
Frank T. Manheim, U.S. Geological Survey, Woods Hole, Massachusetts 02543, USA
Candice M. Lane-Bostwick, U.S. Geological Survey, Woods Hole, Massachusetts 02543, USA
Lawrence G. Sullivan, Lamont-Doherty Earth Observatory, Palisades, New York 10964, USA
Atsuyuki Mizuno, Geological Survey of Japan, Higashi 1-1-3, Tsukuba, Ibaraki, 305-Japan
Gretchen Luepke, U.S. Geological Survey, Menlo Park, California 94025, USA

*Affiliations are at time of compilation

**MAP PRODUCTION BY U.S. GEOLOGICAL SURVEY**
**Compilation coordinated by George Gryc and Warren O. Addicott**
**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: 35° N., 150° E.)

**1999**

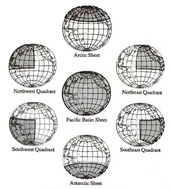
## CIRCUM-PACIFIC MAPS

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 such phenomena as geology, tectonics, and crustal dynamics. The project is 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, and the Arctic and Antarctic areas. Eight series of maps are being published at a scale of 1:10 million for future publication: Geographic, Base, Plate Tectonic, Geodynamic, Geologic, Mineral-Resources, and Energy-Resources.

The 12-sheet mineral-resources map covers 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: therefore, some have been largely or entirely mined out, but they are included as indicative of where elements have been concentrated by geological processes to form ores in the past and thus may suggest favorable areas 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 and crusts that contain appreciable amounts of nickel, copper, and cobalt, and minor amounts of other metals; (2) deposits of zinc, copper, and other metallic sulfides that form by hydrothermal activity along active spreading ridges (and possibly at inactive ridges); and (3) accumulations of phosphorite-bearing crusts, nodules, and finer grained material on the seafloor or in near-bottom sediment.

## LAND RESOURCES

**Commodities**—Shown by shape and color of symbol

| | | | |
|---|---|---|---|
| W | Sn | Sn W | Be | Nb(Ta)U |
| Cu(Au+Ag) | Mo | Cu(Mo | Cu(Zn(Pb+Ag+Au) | Cu(Ni |
| Au(Ag) | Ag(Pt,Zr,Cu,Au) | Au+Ag, Ag+Au | P, precious gems | Semi-precious gems |
| B | Fe(S | Nitrate | Li | B |
| Cr | Ni(Cu,CuPt) | Cu(Ni) | Pt group | Asbestos |
| Ni | Fe | | Gypsum-anhydrite | Magnesite |
| Pb | Zr | Pb,Zn, Zn(Pb | Zn(Au,Ag,Cu,Au) | |
| Hg | Sb | F | Au | Sn |
| U | V | V, V U | REE(Th | Au |
| Fe | Mn | Ti | Fe(Ti,V) | P* |

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

**Age of mineralization**—Geologic age of mineralization shown by double ticks on some deposits. Age known only as "not younger than" or "not older than" indicated by a hook on the age tick.

1. Precambrian
2. Early Paleozoic
3. Late Paleozoic to Triassic
4. Jurassic to Early Cretaceous
5. Late Cretaceous
6. Paleogene
7. Neogene
8. Quaternary

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

- Veins and shear-zone fillings
- Stratabound, including stratiform 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)

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

| 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 ($BaSO_4$) | 500,000 | 50,000 | |
| Beryllium (BeO) | 1,000 | 10 | |
| Boron ($B_2O_3$) | 10,000,000 | 100,000 | |
| Chromium ($Cr_2O_3$) | 1,000,000 | 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) | 200 | 10 | |
| Graphite (C) | 1,000,000 | 10,000 | |
| Gypsum-anhydrite ($CaSO_4$) | 100,000,000 | 5,000,000 | |
| Iron (ore) (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 (Tons of $_{35\%}$ Mn) | 10,000,000 | 100,000 | |
| Mercury (flasks) (Hg) | 500,000 | 10,000 | |
| Molybdenum (Mo) | 500,000 | 25,000 | |
| 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) | 500 | 25 | |
| Potassium ($K_2O$) | 10,000,000 | 1,000,000 | |
| Precious gems | 10 | 1 | |
| Pyrite ($FeS_2$) | 20,000,000 | 200,000 | |
| Rare earths ($RE_2O_3$) | 1,000,000 | 1,000 | |
| Semi-precious gems | 10,000 | 500 | |
| Silver (Ag) | 10,000 | 500 | |
| Sodium (soda) (Na) | 10,000,000 | 1,000,000 | |
| Strontium (celes) (Sr) | 1,000,000 | 10,000 | |
| Sulfur (S) | 10,000,000 | 100,000 | |
| Thorium (Th) | 10,000 | 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 | 100 | |
| Vanadium (V) | 10,000 | 500 | |
| Zinc (Zn) | 1,000,000 | 50,000 | |

**BASE MAP**

Bathymetric contours—Depth of water in meters

- Cities 1,000,000 or more people
- Cities less than 1,000,000 people

4317 Heights in meters

**Active plate boundaries**—Dashed where inferred

- **Spreading ridge**
- **Transform fault**—Dashed where inferred
- **Subduction zone**—Sawteeth on upper plate
- **Complex transform fault boundary**—With elements of dilation

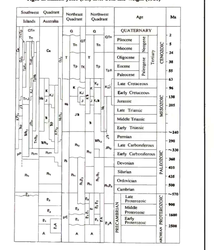
**Seafloor sediment**—Character of surficial sediments shown by pattern and(or) color

- Terrigenous silt/sand/gravel
- Clay, pelagic clay
- Biosiliceous ooze/clay*
- Calcareous ooze/clay*

*Coarser material indicated by stipple pattern

## DESCRIPTION OF MAP UNITS

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




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

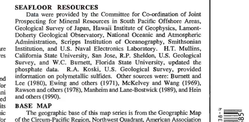
- **Surficial deposits**—a, mostly marine; b, mostly nonmarine
- **Volcanic rocks (Cenozoic to Paleozoic)**—a, felsic; b, felsic to intermediate; c, intermediate; d, intermediate to mafic; e, mafic; f, sedimentary and(or) metamorphosed
- **Platform cover (Phanerozoic and Late Proterozoic)**—a, mostly marine; b, mostly nonmarine
- **Basinal and marginal deposits**—a, mostly marine; b, mostly nonmarine
- **Folded continental margin rocks (Phanerozoic and Late Proterozoic)**—Unmetamorphosed to slightly metamorphosed; a, mostly marine; b, mostly nonmarine
- **Metamorphic complexes (Phanerozoic)**
- **Crystalline basement rocks (Early and Middle Proterozoic and Archean)**—Plutonic, volcanic, and metasedimentary
- **Intrusive igneous rock**—a, felsic; b, intermediate; c, mafic; d, alkaline
- **Ultramafic rocks**
- **Contact**
- **Faulted contact**

## 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 Geological 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**—Areas where seafloor coverage is greater than 10 percent are indicated by diagonal ruled pattern

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

- + ≥1.8% nickel plus copper
- + 1.0–1.79% nickel plus copper
- + <1.0% nickel plus copper
- + ≥35% manganese
- + ≥1.0% cobalt

Outline of area for which analyses average 1.8% or more nickel plus copper

### MANGANESE CRUSTS

**Cobalt content**—In percent. Cobalt data normalized to a hydrocopic moisture and substrate- (dcrital matter) free basis. The algorithm to obtain these values is given by $Co^* = Co \times 51.23 / (Fe+Mn)$ (Manheim and Lane-Bostwick, 1989)

- + <0.5
- + 0.5–1.0
- + 1.0–1.5
- + >1.5

### POLYMETALLIC HYDROTHERMAL DEPOSITS

- Seafloor sulfide
- Sub-seafloor sulfide—Number refers to Deep Sea Drilling Project (DSDP) or Ocean Drilling Project (ODP) site number
- Submarine hot spring

### NON-METALLIC DEPOSITS

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

## REFERENCES CITED

Balce, G.R., Crispin, O.A., Sienaesingn, C.M., and Miranda, C.R., 1981, Metallogenesis in the Philippines—Explanatory text for the Commission for the Geological Map of the World– Metallogenic map of Philippines, *in* Ishihara, S., and Suzuki, A., eds., 1981, Metallogeny of Asia: Geological Survey of Japan Report, no. 261, p. 125-148.

Burnett, W.C., and Lee, A.I.N., 1980, The phosphate supply system in the Pacific region: Geojournal, v. 4, no. 5, p. 423-436.

Djamluddin, 1981, Metallic mineral deposits of Indonesia—a metallogenic approach, *in* Ishihara, S., and Suzuki, A., eds., Metallogeny of Asia: Geological Survey of Japan Report, no. 261, p. 107-124.

Ewing, J., Ewing, M., Sullivan, L., Aitken, T., and Thorndike, E., 1971, Phosphorite-bearing manganese nodules on the ocean floor: Oceanology International, v. 6, no. 12, p. 26-32.

Goossens, P.J., 1981, The metallogenic provinces of Burma, *in* Nutalaya, Prinya, ed., Regional Conference on Geology and Mineral Resources of Southeast Asia, 3d, Bangkok, 1978, Proceedings: Geology and Mineral Resources of Southeast Asia: Geological Society of Thailand, v. 3, no. 1, p. 434-490.

Heiin, J.R., and others, 1990, Geological, geochemical, geophysical, and oceitographic data and interpretations of seamounts and Co-rich ferromanganese crusts from the Marshall Islands, KORDI-U.S.G.S. R.V. *Farnella* Cruise F10-89-CP: U.S. Geological Survey Open File Report 90-437, 246 p.

Inoue, Eiji, chairman, 1988, Geologic map of the circum-Pacific region, northwest quadrant: Circum-Pacific Council for Energy and Mineral Resources, scale 1:10,000,000, 30 p.

Kanehira, K., and others, 1984-85, Metallogenic map of South and East Asia: Commission for the Geological Map of the World, scale 1:5,000,000, 4 sheets and 1 explanatory sheet.

Kim, S.E., and Hwang, D.H., 1983, Metallogenic map of Korea: Korea Institute of Energy Resources, Metallic Minerals Division, Economic Geology Department, scale 1:1,000,000 with explanatory text.

Mero, J.L., 1965, The mineral resources of the sea: Amsterdam, Elsevier Oceanography Series, 312 p.

Moore, G.W., 1967, Plate perimeters and motion vectors, *in* Inoue, Eiji, chairman, Plate-tectonic map of the circum-Pacific region, northwest quadrant: Circum-Pacific Council for Energy and Mineral Resources, scale 1:10,000,000, 14 p.

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

Sohl, N.F., and Wright, W.B., 1980, Changes in stratigraphic nomenclature by the U.S. Geological Survey: U.S. Geological Survey Bulletin 1502-A, p. A1-2.

Takashima, K., and Igarashi, T., 1973, Metallogenic map of Japan: Geological Survey of Japan, scale 1:2,000,000.

## SOURCES OF DATA

### GEOLOGIC BACKGROUND

Land geology is generalized from Inoue (1988). Seafloor sediment data are generalized from McCoy (1988). Active plate boundaries and intraplate structures from Moore (1987), updated in 1990.

### LAND RESOURCES

Land and offshore data sources of Southeast Asia—Thailand, Malaysia, and Philippines— are the Metallogenic Map of South and East Asia, Commission for the Geological Map of the World (Kanehira and others, 1984-85) and Djamluds (1981), Balce and others (1981), and Goossens (1980). USSR data were provided by E.A. Radkevich, Far East Geological Institute, Vladivostok. Mineral deposits of the Korean peninsula and Japan were compiled mainly from the metallogenic maps (Kim and Hwang, 1983, and Takashima and Igarashi, 1973). Data for mainland China were taken from various geoscientific journals and monographs published in China. The overlap area between the Northwest and the Southwest Quadrants were adjusted based on data provided by W.D. Palfreyman, Bureau of Mineral Resources, Australia.

### SEAFLOOR RESOURCES

Data were provided by the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas, Geological Survey of Japan, Hawaii Institute of Geophysics, Lamont-Doherty Geological Observatory, National Oceanic and Atmospheric Administration, Scripps Institution of Oceanography, Southeastern Institution, and U.S. Naval Electronics Laboratory. H.T. Mullins, California State University, San Jose, R.P. Sheldon, 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 polymetallic sulfides. Other sources were: Burnett and Lee (1980), Ewing and others (1971), McKelvey and Wang (1969), Rawson and others (1978), Manheim and Lane-Bostwick (1989), and Hein and others (1990).

### BASE MAP

The geographic base of this map series is from the Geographic Map of the Circum-Pacific Region, Northwest Quadrant, American Association of Petroleum Geologists, 1977. The map was compiled by the U.S. Geological Survey, Reston, Virginia, and modified in 1991.

For additional information regarding compilation of this map, see the accompanying Explanatory Notes pamphlet.

Base by U.S. Geological Survey, 1978.
Modified in 1991.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1999

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225