CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the Grover Heinrichs Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGIC AND WATER-SUPPLY REPORTS AND MAPS

IDAHO

IDAHO

January 1971

This list contains reports and maps published by the Geological Survey relating to the geology and mineral and water resources of Idaho. A separate list of bibliographies and publications of general interest is available on request, as are a general catalog of Geological Survey publications (not including topographic maps), and State indexes to topographic mapping.

AN ASTERISK (*) INDICATES THAT THE PUBLICATION IS OUT OF PRINT AND NOT PURCHASABLE FROM ANY OFFICIAL SOURCE. Bulletins, professional papers, and water-supply papers for which a price is stated are for sale by the SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, prepayment being required. Numerous libraries and educational institutions throughout the country are depositories for this material and a list of Idaho depositories is included.

Maps, folios hydrologic atlases and charts are sold by the Geological Survey. They may be ordered from the WASHINGTON DISTRIBUTION SECTION, U.S. GEOLOGICAL SURVEY, 1200 S. EADS STREET, ARLINGTON, VA. 22202, or from the DENVER DISTRIBUTION SECTION, U.S. GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLO. 80225. Remittances should be made by check or money order payable to the Geological Survey. A discount of 20 percent is allowed on orders of $20 or more, and 40 percent on orders of $100 or more, based on the retail price. Maps, charts, hydrologic atlases, bulletins, professional papers, and water-supply papers, that are available, may be purchased over the counter only at the following GEOLOGICAL SURVEY offices: 8102 Federal Office Building, Salt Lake City, Utah, and Room 678 U.S. Court House Bldg., Spokane, Washington.

Reference to geologic information on Idaho may be obtained from the following Geological Survey publications: Geologic Map Index of Idaho, described herein, from Bibliographies of North American geology — Bulletins *746 (1785-1918) *747 (1785-1918), 823 (1919-1928) $3, 937 (1929-1939) $4.25, *1049 (1940-1949), *985 (1950), *1025 (1951), 1035 (1952-1953) $2, 1054 (1954) $1.50, *1065 (1955), *1075 (1956), *1095 (1957), 1115 (1958), *1145 (1959), *1195 (1950-1959) set of 4 volumes, 1196 (1960) $2.25, *1197 (1961), *1232 (1962), 1233 (1963) $3.25, *1234 (1964), 1235 (1965) $4.75, 1266 (1966) $4.75, and 1267 (1967) $4.25. Bibliographies and indexes of publications relating to ground water are Water-Supply Papers *992 (1879-1945), *1492 (1946-1955), 1863 (1963) 55c, and 1864 (1964) $1. A water resources investigations folder, available free upon request to the Geological Survey, Washington, D.C. 20242, shows the location of stream-gaging stations, observation wells, quality-of-water sample collection sites, areal hydrologic studies, average annual runoff, average discharge of principal streams, and availability of ground water. A brief text lists the hydrologic network, the areal and Statewide projects, and selected references.

Additional information is obtainable from the Director, Idaho Bureau of Mines and Geology, Moscow, Idaho 83843.

Information on altitudes in the United States is contained in Bulletins *5, *76, *160, *274, *689, *817, and 1212 ($1.75); information on boundaries and areas of the United States, with historical outlines of boundary changes, is contained in Bulletins *13, *171, *226, *302, *689, *817, and 1212 ($1.75); information on results of primary triangulation and primary traverse from 1894 to 1918 is contained in Bulletins *122, *181, *201, *216, *245, *276, *310, *440, *496, *551, *644, *709, and *Parts 1 of the *18th, *19th, *20th, and *21st Annual Reports. Further information on more recent triangulation, transit traverse, and spirit leveling in Idaho is obtainable upon specific request.

Current publications are announced by means of monthly notices, "New Publications of the Geological Survey." Free on application to the Geological Survey, Washington, D.C. 20242.

ANNUAL REPORTS

*Twelfth, 1890-91. 1891. Part 1 contains: The Lafayette formation, by W J McGee. p. 347-521.

*Sixteenth, 1894-95. 1896. Part 2 (1985) contains: A geological reconnaissance across Idaho, by G. H. Eldridge. p. 211-276.

*Eighteenth, 1896-97. 1897. Part 3 (1898) contains: The mining districts of the Idaho Basin and the Boise Ridge, Idaho, by Waldemar Lindgren, with a report on the fossils plants of the Payette formation, by F. H. Knowlton. p. 617-744.

*Nineteenth, 1897-98. 1898. Part 5 (1899) contains: Priest River Forest, by J. B. Leiberg. p. 217-252; Bitterroot Forest Reserve, J. B. Leiberg. p. 253-283; and Forest conditions of northern Idaho, by J. B. Leiberg. p. 373-386.

*Twentieth, 1898-99. 1899. Part 3 (1900) contains: The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho, by Waldemar Lindgren. p. 65-256. Part 5 (1900) contains: The Flathead Forest Reserve, by H. B. Ayres. p. 245-316; and Bitterroot Forest Reserve, by J. B. Leiberg. p. 317-410.

*Twenty-second, 1900-1901. 1901. Part 3 (1902) contains: Coal fields of the United States, by C. W. Hayes. p. 7-24; and The Rocky Mountain coal fields, by L. S. Storrs. p. 415-471.

(Beginning with the twenty-third (1901-02), the annual reports of the Geological Survey contain no technical papers but were published separately until 1933. Since 1933 a condensed form has been included in the annual report of the Secretary of the Interior. For the fiscal years 1936 to 1963, a limited number of copies of the report as it appeared in the annual report of the Secretary were reprinted separately for official use; copies of these may be had free by persons directly interested, insofar as they are in stock.)

MINERAL RESOURCES OF THE UNITED STATES

The annual volumes of Mineral Resources of the United States contain statistics of production by calendar years and matters relating to technology and resources. Some of the chapters deal with a particular mineral or group of minerals but much of the information is statistical. These volumes are not listed. The volumes of Mineral Resources were issued by the Geological Survey for the years 1882 to 1923. Reports for 1924 and subsequent years are published by the Bureau of Mines, Washington, D.C. 20240, as Minerals Yearbooks.

MONOGRAPHS

*1. Lake Bonneville, by G. K. Gilbert. 1890. 438 p., 1 map.

*10. Dinocerata, a monograph of an extinct order of gigantic mammals, by O. C. Marsh. 243 p.

*32. Geology of the Yellowstone National Park—Part 2, by Arnold Hague and others. 1899. 893 p. *Atlas (27 sheets folio). (Part 1 not published.)

*51. Cambrian Brachiopoda, by C. D. Walcott. 1912. In two parts. Part 1, 872 p.; Part 2, 363 p.

*54. The Mesozoic and Cenozoic Echinodermata of the United States, by W. B. Clark and M. W. Twitchell. 1915. 341 p.

GEOLOGIC FOLIOS

*45. Boise, Idaho, by Waldemar Lindgren. 1898. 7 p., 4 maps.

103. Nampa, Idaho-Oreg., by Waldemar Lindgren and N. F. Drake. 1904. 5 p., 2 maps.

104. Silver City, Idaho, by Waldemar Lindgren and N. F. Drake. 1904. 6 p., 3 maps.

PROFESSIONAL PAPERS

*27. A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, by Waldemar Lindgren. 1904. 123 p.

*40. The Triassic cephalopod genera of America, by Alpheus Hyatt and J. P. Smith. 1905. 394 p.

*62. The geology and ore deposits of the Coeur d'Alene district, Idaho, by F. L. Ransome and F. C. Calkins. 1908. 203 p. (See also Professional Papers 445 and 478.)

*97. Geology and ore deposits of the Mackay region, Idaho, by J. B. Umpleby. 1917. 129 p.

*98. Shorter contributions to general geology, 1916. 1917. Contains: Revision of the Beckwith and Bear River formations of southeastern Idaho, by G. R. Mansfield and P. V. Roundy. p. 75-84.

*120. Shorter contributions to general geology, 1918. 1919. Contains: Relations of late Paleozoic and early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming, by D. D. Condit. p. 111-121.

*132. Shorter contributions to general geology, 1923-24. 1925. Contains: A new fauna from the Colorado group of southern Montana, by J. B. Reeside, Jr. p. 25-33; Discovery of a Balkan fresh-water fauna in the Idaho formation of Snake River Valley, Idaho, by W. H. Dall. p. 109-115.

*140. Shorter contributions to general geology, 1925. 1926. Contains: Geology of the Latah formation in relation to the lavas of the Columbia Plateau near Spokane, Wash., by J. T. Pardee and Kirk Bryan. p. 1-16; Flora of the Latah formation of Spokane, Wash., and Coeur d'Alene, Idaho, by F. H. Knowlton. p. 17-81.

*152. Geography, geology, and mineral resources of part of southeastern Idaho, by G. R. Mansfield, with descriptions of Carboniferous and Triassic fossils, by G. H. Girty. 1927. 453 p.

*154. Shorter contributions to general geology, 1928. 1929. Contains: A revision of the flora of Latah formation, by E. W. Berry. p. 225-265.

*158. Shorter contributions to general geology, 1929. 1930. Contains: Contact metamorphism of the rocks in the Pend Oreille district, northern Idaho, by J. L. Gillson. p. 111-121; Early Pleistocene glaciation in Idaho, by C. P. Ross. p. 123-128.

*167. Lower Triassic ammonoids of North America, by J. P. Smith. 1932. 199 p.

*185-E. Miocene plants from Idaho, by E. W. Berry. 1934 (1935). p. 97-125.

PROFESSIONAL PAPERS--Continued

*186-F. American Cretaceous ferns of the genus *Tempskya*, by C. B. Read and R. W. Brown. 1937. p. 105-131.

*186-J. Additions to some fossil floras of the Western United States, by R. W. Brown. 1937. p. 163-206.

*202. Geology and ore deposits of the Metaline quadrangle, Washington, by C. F. Park, Jr., and R. S. Cannon, Jr. 1943. 81 p. (See also Professional Paper 489.)

*229. Mica and beryl pegmatites in Idaho and Montana, by W. C. Stoll. 1950 (1951). 64 p.

*231. Physiography and glacial geology of Western Montana and adjacent areas, by W. C. Alden. 1953 (1954). 300 p.

*238. Geography, geology, and mineral resources of the Ammon and Paradise Valley quadrangles, Idaho, by G. R. Mansfield. 1952 (1953). 92 p.

*250. American Triassic coiled nautiloids, by Bernhard Kummel. 1953. 104 p.

*254-H. Triassic stratigraphy of southeastern Idaho and adjacent areas, by Bernhard Kummel. 1954. p. 165-194.

*272-D. Evaporation from the 17 Western States, by J. S. Meyers, with a section on Evaporation rates, by T. J. Nordenson, U.S. Weather Bureau. 1962. p. 71-100.

294-A. North American Mesozoic Charophyta, by R. E. Peck. 1957. p. 1-44. $1.

*294-D. Stromatolites of the Belt Series in Glacier National Park and vicinity, Montana, by Richard Rezak. 1957. p. 127-154.

*294-L. Brachiopod fauna of Saturday Mountain formation, southern Lemhi Range, Idaho, by R. J. Ross, Jr. 1959. p. 441-461.

313-A. The Phosphoria, Park City, and Shedhorn formations in the western phosphate field, by V. E. McKelvey and others. 1959. p. 1-47. $1.

313-B. Physical stratigraphy and mineral resources of Permian rocks in western Wyoming, by R. P. Sheldon. 1963. p. 49-273. $2.75.

*313-C. Stratigraphy and petrology of the Permian rocks of southwestern Montana, by E. R. Cressman and R. W. Swanson. 1964. p. 275-569.

313-D. Biostratigraphy of the Phosphoria, Park City, and Shedhorn Formations, by E. L. Yochelson, with a section on Fish, by D. H. Van Sickle. 1968. p. 571-660. 60c.

*318. Occurrence of nonpegmatite beryllium in the United States, by L. A. Warner, W. T. Holser, V. R. Wilmarth, and E. N. Cameron. 1959. 198 p. (See also Map MR-35.).

*344-A. Metasomatic metamorphism in western Clearwater County, Idaho, by Anna Hietanen. 1962. p. A1-A116.

*344-B. Anorthosite and associated rocks in the Boehls Butte quadrangle and vicinity, Idaho, by Anna Hietanen. 1963. p. B1-B78.

*344-C. Metamorphism of the Belt series in the Elk River—Clarkia area, Idaho, by Anna Hietanen. 1963 (1964). p. C1-C49.

*344-D. Idaho batholith near Pierce and Bungalow, Clearwater County, Idaho, by Anna Hietanen. 1963 (1964). p. D1-D42.

344-E. Belt series in the region around Snow Peak and Mallard Peak, Idaho, by Anna Hietanen. 1968. p. E1-E34. $1.50.

356-A. Oil yield and uranium content of black shales, by V. E. Swanson. 1960. p. 1-44. 30c.

*356-D. Geology of uranium in coaly carbonaceous rocks, by J. V. Vine. 1962. p. 113-170.

*366. Ash-flow tuffs: Their origin, geologic relations, and identification, by C. S. Ross and R. L. Smith. 1961. 81 p.

PROFESSIONAL PAPERS--Continued

374-J. The Bannock thrust zone, southeastern Idaho, by F. C. Armstrong and E. R. Cressman. 1963. p. J1-J22. $1.25.

383-A. Storage of ground water behind subsurface dams in the Columbia River basalt, Washington, Oregon, and Idaho, by R. C. Newcomb. 1961 (1962). p. A1-A15. 20c.

*400-A. Geological Survey Research 1960, Synopsis of geologic results. p. A1-A136.

*400-B. Short papers in the geological sciences, Articles 1-232. 1960. p. B1-B515. Contains the following articles, which are not available separately.

2. Varieties of supergene zinc deposits on the United States, by A. V. Heyl, Jr., and C. N. Bozion. p. B2.
13. Tectonic setting of the Coeur d'Alene district, Idaho, by R. E. Wallace, A. B. Griggs, A. B. Campbell, and S. W. Hobbs. p. B25.
14. Bleaching in the Coeur d'Alene district, Idaho, by P. L. Weis. p. B27.
15. Origin of the Main period veins, Coeur d'Alene district, Idaho, by V. C. Fryklund, Jr. p. B29.
103. Metamorphism and thrust faulting in the Riggins quadrangle, Idaho, by Warren Hamilton. p. B230.
104. Diverse interfingering Carboniferous strata in the Mackay quadrangle, Idaho, by C. P. Ross. p. B232.
135. Evidence in the Snake River Plain, Idaho, of a catastrophic flood from Pleistocene Lake Bonneville, by H. E. Malde. p. B295.
136. Alkalic lava flow with fluidity of basalt, in the Snake River Plain, Idaho, by H. A. Powers. p. B297.
137. A distinctive chemical characteristic of Snake River basalts of Idaho, by H. A. Powers. p. B298.
216. Determination of zinc in basalts and other rocks, by L. F. Rader, W C Swadley, H. H. Lipp, and Claude Huffman, Jr. p. B477.

417-D. Chemical quality of the surface waters of the Snake River basin, by L. B. Laird. 1964. p. D1-D47. $1.

424-A. Geological Survey Research 1961, Synopsis of geologic and hydrologic results. 1961. p. A1-A194. $1.50.

*424-B. Short papers in the geologic and hydrologic sciences, Articles 1-146. 1961. p. B1-B344. Contains the following articles, which are not available separately.

8. Recent hydrologic trends in the Pacific Northwest, by W. D. Simons. p. B17.
17. Hydrologic significance of buried valleys in glacial drift, by S. E. Norris and G. W. White. p. B34.
67. Structure of the Clark Fork area, Idaho—Montana, by J. E. Harrison, D. A. Jobin, and Elizabeth King. p. B159.
68. Pleistocene geology of the central part of the Lemhi Range, Idaho, by E. T. Ruppel and M. H. Hait, Jr. p. B163.
69. The Michaud delta and Bonneville River near Pocatello, Idaho, by D. E. Trimble and W. J. Carr. p. B164.
70. Volcanic ash beds as stratigraphic markers in basin deposits near Hagerman and Glenns Ferry, Idaho, by H. A. Powers and H. E. Malde. p. B167.
71. Patterned ground of possible solifluction origin at low altitude in the western Snake River Plain, Idaho, by H. E. Malde. p. B170.
88. Structural barrier reservoirs of ground water in the Columbia River basalt, by R. C. Newcomb. p. B213.

*424-B--Continued

99. Corals from Permian rocks of the northern Rocky Mountain region, by Helen Duncan. p. B235.
100. Occurrences of the Permian gastropod *Omphalotrochus* in Northwestern United States, by E. L. Yochelson. p. B237.
104. Gravity, volcanism, and crustal deformation in and near Yellowstone National Park, by L. C. Pakiser and H. L. Baldwin, Jr. p. B246.
105. Gravity, volcanism, and crustal deformation in the Snake River Plain, Idaho, by D. P. Hill, H. L. Baldwin, Jr., and L. C. Pakiser. p. B248.

*424-C. Short papers in the geologic and hydrologic sciences, Articles 147-292. 1961. p. C1-C398. Contains the following articles, which are not available separately.

195. Proposed classification of ground-water provinces, hydrologic units, and chemical types of ground water in the Upper Colorado River Basin, by D. A. Phoenix. p. C125.
212. A redefinition and restriction of the term Challis volcanics, by C. P. Ross. p. C177.
213. Upper Paleozoic rocks in the Deep Creek Mountains, Idaho, by W. J. Carr and D. E. Trimble. p. C181.
236. Stratigraphic distribution of endothyrid Foraminifera in Carboniferous rocks of the Mackay quadrangle, Idaho, by B. A. L. Skipp. p. C239.
267. Metal content of some black shales of the Western United States, by D. F. Davidson and H. W. Lakin. p. C329.

424-D. Short papers in the geologic and hydrologic sciences, Articles 293-435. 1961. p. D1-D408. $2.75. Contains the following articles, which are not available separately.

345. Relation between deformation, metamorphism, matasomatism, and intrusion along the northwest border zone of the Idaho batholith, Idaho, by Anna Hietanen. p. D161.
382. Stratigraphic significance of the Cretaceous ferm Tempskya in the western conterminous United States, by C. B. Read and S. R. Ash. p. D250.
406. Geographic distribution of major constituents in stream waters of the western conterminous United States, by C. E. Roberson. p. D334.
420. Hydrology of radioactive-waste disposal at the Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho, by P. H. Jones. p. D374.

*426. Data on uranium and radium in ground water in the United States, 1954 to 1957, by R. C. Scott and F. B. Barker. 1962. 115 p.

*436. Metamorphism in the Riggins region, western Idaho, by Warren Hamilton. 1963. 95 p.

*445. Ore deposits of the Coeur d'Alene district, Shoshone County, Idaho, by V. C. Fryklund, Jr., with a section on The bleached rock in the Coeur d'Alene district, by P. L. Weis. 1964. 103 p. (See also Professional Paper 478.)

*450-A. Geological Survey Research 1962, Synopsis of geologic, hydrologic and topographic results. 1962. p. A1-A257.

*450-B. Short papers in geology, hydrology, and topography, Articles 1-59. 1962. Contains the following articles, which are not available separately.

5. Old metavolcanic rocks of the Big Creek area, central Idaho, by B. F. Leonard. p. B11.
10. Volcanic rocks of Oligocene age in the southern part of the Madison Range, Montana and Idaho, by Warren Hamilton and E. E. Leopold. p. B26.

PROFESSIONAL PAPERS--Continued

*450-C. Short papers in geology and hydrology. Articles 60-119. 1962. p. C1-C146. Contains the following articles, which are not available separately.

83. Staurolite zone near the St. Joe River, Idaho, by Anna Hietanen. p. C69.
85. Metal content of some black shales of the Western Conterminous United States—Part 2, by D. F. Davidson and H. W. Lakin. p. C74.
106. Hydrology of radioactive-waste disposal in the MTR-ETR area, National Reactor Testing Station, Idaho, by P. H. Jones and Eugene Shuter. p. C113.

*450-D. Short papers in geology, hydrology, Articles 120-179. 1962. p. D1-D195. Contains the following articles, which are not available separately.

140. Gravity and magnetic anomalies in Gem Valley, Caribou County, Idaho, by D. R. Mabey and F. C. Armstrong. p. D73.
141. Gravity, volcanism, and crustal deformation in the eastern Snake River Plain, Idaho, by T. R. LaFehr and L. C. Pakiser. p. D76.

*450-E. Short papers in geology, hydrology, and topography, Articles 180-239. 1963. Contains the following articles, which are not available separately.

204. Syenite complex older than the Idaho batholith, Big Creek quadrangle, central Idaho, by B. F. Leonard. p. E93.
205. Trondhjemite in the Riggins quadrangle, western Idaho, by Warren Hamilton. p. E98.
211. Menan Buttes, cones of glassy basalt tuff in the Snake River Plain, Idaho, by Warren Hamilton and W. B. Myers. p. E114.

454-E. New data on the isostatic deformation of Lake Bonneville, by M. D. Crittenden, Jr. 1963. p. E1-E31. 30c.

*455-A-F. Geology of uranium-bearing veins in the conterminous United States. 1963 (1964). 120 p. Includes the following chapters.

A. Introduction to the geology of uranium-bearing veins in the conterminous United States, including sections on geographic distribution and classification of veins, by G. W. Walker and F. W. Osterwald. p. 1-28.
B. Age of uranium-bearing veins in the conterminous United States, by G. W. Walker. p. 29-35.
C. Host rocks and their alterations as related to uranium-bearing veins in the conterminous United States, by G. W. Walker. p. 73-63.
D. Mineralogy, internal structure and textural characteristics, and paragenesis of uranium-bearing veins in the conterminous United States, by G. W. Walker and J. W. Adams. p. 55-90.
E. Supergene alteration of uranium-bearing veins in the conterminous United States, by G. W. Walker. p. 91-103.
F. Concepts of origin of uranium-bearing veins in the conterminous United States, by G. W. Walker and F. W. Osterwald. p. 105-120.

*455-G. Structural control of uranium-bearing vein deposits and districts in the conterminous United States, by F. W. Osterwald. 1965. p. 121-146. Includes title page and contents for volume.

*475-A. Geological Survey Research 1963, Summary of Investigations. 1963. p. A1-A300.

*475-B. Short papers in geology and hydrology, Articles 1-59. 1963. p. B1-B219. Contains the following articles, which are not available separately.

5. Beryllium and fluorine content of some silicic volcanic glasses from Western United States, by W. R. Griffits and H. A. Powers. p. B18.

475-B--Continued

6. Some new data on the arsenic content of basalt, by A. J. Bartel, E. J. Fennelly, Claude Huffman, Jr., and L. F. Rader, Jr. p. B20.
23. Age of certain post-Madison rocks in southwestern Montana and western Wyoming, by J. T. Dutro, Jr., and W. J. Sando. p. B93.
32. Paleocology of the Permian Phosphoria Formation and related rocks, by E. L. Yochelson. p. B123.

*475-C. Short papers in geology and hydrology. Articles 60-121. 1963. Contains the following articles, which are not available separately.

80. Petrology of rhyolite and basalt, northwestern Yellowstone Plateau, by Warren Hamilton. p. C78.
82. Modal composition of the Idaho batholith, by C. P. Ross. p. C86.

*475-D. Short papers in geology and hydrology. Articles 122-172. 1964. p. D1-D223. Contains the following articles, which are not available separately.

122. Comparison of late Paleozoic depositional history of northern Nevada and central Idaho, by R. J. Roberts and M. R. Thomasson. p. D1.
162. Relation of percent sodium to source and movement of ground water, National Reactor Testing Station, Idaho, by F. H. Olmsted. p. D186.

*478. Geology of the Coeur d'Alene district, Shoshone County, Idaho, by S. W. Hobbs, A. B. Griggs, R. E. Wallace, and A. B. Campbell. 1965. 139 p.

*483-D. Upper Jurassic mollusks from eastern Oregon and western Idaho, by R. W. Imlay. 1964. p. D1-D21.

*489. Geology and ore deposits of the Metaline zinc-lead district, Pend Oreille County, Wash., by McC. G. Dings and D. H. Whitebread. 1965. 109 p.

*491-A. Introduction, spread, and areal extent of saltcedar (Tamarix) in the Western United States, by T. W. Robinson. 1965. p. A1-A12.

*492. Thermal springs of the United States and other countries of the world—A summary, by G. A. Waring, revised by R. R. Blankenship and Ray Bentall. 1965. 383 p.

*501-A. Geological Survey Research 1964. 1964. p. A1-A367.

*501-C. Geological Survey Research 1964. 1964. p. C1-C197. Contains the following article, which is not available separately.

Strike-slip faulting and broken basin-ranges in east-central Idaho and adjacent Montana, by E. T. Ruppel. p. C14.

*503-E. Revision of some Paleozoic coral species from the Western United States, by W. J. Sando. 1965. p. E1-E38.

504-C. Geology and petrogenesis of the Island Park caldera of rhyolite and basalt, eastern Idaho, by Warren Hamilton .1965. p. C1-C37.

*525-A. Geological Survey Research 1965. 1965 (1966). p. A1-A376.

*525-B. Geological Survey Research 1965. 1965. p. B1-B195. Contains the following article, which is not available separately.

Mercury-bearing antimony deposit between Big Creek and Yellow Pine, central Idaho, by B. F. Leonard. p. B23.

*525-C. Geological Survey Research 1965. 1965. p. C1-C219. Contains the following articles, which are not available separately.

Stratigraphic data bearing inferred pull-apart origin of Gem Valley, Idaho, by S. S. Oriel, D. R. Mabey, and F. C. Armstrong. p. C1.

Seismic-refraction measurements of crustal structure between American Falls Reservoir, Idaho, and Flaming Gorge Reservoir, Utah, by Ronald Willden. p. C44.

PROFESSIONAL PAPERS--Continued

525-C--Continued

Maximum extent of late Pleistocene Cordilleran glaciation in northeastern Washington and northern Idaho, by P. L. Weis and G. M. Richmond. p. C128.

530. The geologic occurrence of monazite, by W. C. Overstreet. 1967. 327 p. $3.

538. Geology of epigenetic uranium deposits in sandstone in the United States, by W. I. Finch. 1967. 121 p. $1.50.

540. Twin Creek Limestone (Jurassic) in the western interior of the United States, by R. W. Imlay. 1967. 105 p. $1.25.

544-C. Hydrologic effects of the earthquake of March 27, 1964, outside Alaska, by R. C. Vorhis, E. E. Rexin, and R. W. Coble. 1967. p. C1-C54. 45c.

550-A. Geological Survey Research 1966. 1966 (1967). p. A1-A385. $2.50.

550-B. Geological Survey Research 1966. 1966. p. B1-B227. Contains the following articles, which are not available separately.

Permian coleoid cephalopods from the Phosphoria Formation in Idaho and Montana, by Mackenzie Gordon, Jr. p. B28.

Relation between Bouguer gravity anomalies and regional topography in Nevada and the eastern Snake River Plain, Idaho, by D. R. Mabey. p. B108.

550-D. Geological Survey Research 1966. 1966. p. D1-D267. $2.25. Contains the following article, which is not available separately.

Reconnaissance survey of ground-water quality in the Great Basin, by J. H. Feth. p. D237.

575-A. Geological Survey Research 1967. 1967. p. A1-A377. $2.25.

*575-B. Geological Survey Research 1967. 1967. p. B1-B265. Contains the following article, which is not available separately.

Varved lake beds in northern Idaho and northeastern Washington, by E. H. Walker. p. B83.

*575-C. Geological Survey Research 1967. 1967. p. C1-C251. Contains the following article, which is not available separately.

Age and regional significance of basal part of Milligen Formation, Lost River Range, Idaho, by C. A. Sandberg, W. J. Mapel, and J. W. Huddle. p. C127.

*575-D. Geological Survey Research 1967. 1967. p. D1-D297. Contains the following articles, which are not available separately.

Northwesterly extension of the Darby thrust in the Snake River Range, Wyoming and Idaho, by H. F. Albee, D. A. Jobin, and M. L. Schroeder. p. D1.

Mississippian depositional provinces in the northern Cordilleran region, by W. J. Sando. p. D29.

*594-C. Silver-rich disseminated sulfides from a tungsten-bearing quartz lode, Big Creek district, central Idaho, by B. F. Leonard, C. W. Mead, and Nancy Conklin. 1968. p. C1-C24.

*596. The catastrophic late Pleistocene Bonneville Flood in the Snake River Plain, Idaho, by H. E. Malde. 1968. 52 p.

600-A. Geological Survey Research 1968. 1968. p. A1-A371. $3.50.

*600-B. Geological Survey Research 1968. 1968. p. B1-B235. Contains the following article, which is not available separately.

Rhabdophane from a rare-earth occurrence, Valley County, Idaho, by J. W. Adams. p. B48.

600-D. Geological Survey Research 1968. 1968. p. D1-D269. $3.25. Contains the following articles, which are not available separately.

A water-balance equation for the Rathdrum Prairie ground-water reservoir, near Spokane, Wash., by E. J. Pulhowski and C. A. Thomas. p. D75.

PROFESSIONAL PAPERS--Continued

600-D --Continued

Devonian paleotectonics in east-central Idaho and southwestern Montana, by W. J. Mapel and C. A. Sandberg. p. D115.

610. Principal gold-producing districts of the United States, by A. H. Koschmann and M. H. Bergendahl. 1968. 283 p. $4.75.

613-E. Carboniferous megafaunal and microfaunal zonation in the northern Cordillera of the United States, by W. J. Sando, B. L. Mamet, and J. T. Dutro, Jr. 1969. p. E1-E29. 75c.

646-D. Geologic implications of aeromagnetic data in the Pend Oreille area, Idaho and Montana, by E. R. King, J. E. Harrison, A. B. Griggs. 1970. p. D1-D17. 75c.

646-E. Gravity and magnetic anomalies in the Soda Springs region, southeastern Idaho, by D. R. Mabey and S. S. Oriel. 1970. p. E1-E15. $1.25.

650-A. Geological Survey Research 1969. 1969 (1970). p. A1-A425. $4.

650-B. Geological Survey Research 1969. 1969. p. B1-B203. $2.25. Contains the following article, which is not available separately.

Ordovician bedded chert, argillite, and shale of the Cordilleran eugeosyncline in Nevada and Idaho, by K. B. Ketner. p. B23.

650-D. Geological Survey Research 1969. 1969. p. D1-D299. $3.75. Contains the following article, which is not available separately.

Diffusion from a gaseous source in a porous medium—A field and theoretical comparison, by J. B. Robertson. p. D265.

700-B. Geological Survey Research 1970. 1970. p. B1-B267. $3.25. Contains the following articles, which are not available separately.

Relation of carbon dioxide content of apatite of the Phosphoria Formation to regional facies, by R. A. Gulbrandsen. p. B9.

Stratigraphic micropaleontology of the type locality of the White Knob Limestone (Mississippian), Custer County, Idaho, by Betty Skipp and B. L. Mamet. p. B118.

700-C. Geological Survey Research 1970. 1970. p. C1-C247. $3.25. Contains the following article, which is not available separately.

Gravity anomalies in Cache Valley, Cache and Box Elder Counties, Utah, and Bannock and Franklin Counties, Idaho, by D. L. Peterson and S. S. Oriel. p. C114.

700-D. Geological Survey Research 1970. 1970 (1971). p. D1-D317. $3.75. Contains the following article, which is not available separately.

Verticle molecular diffusion of xenon-133 gas after injection underground, by J. B. Robertson. p. C287.

BULLETINS

*11. On the Quaternary and Recent Mollusca of the Great Basin, with descriptions of new forms, by R. E. Call, introduced by a sketch of the Quaternary lakes of the Great Basin, by G. K. Gilbert. 1884. 66 p.

*40. Changes in river courses in Washington Territory due to glaciation, by Bailey Willis. 1887. 10 p.

*52. Subaerial decay of rocks and origin of the red color of certain formations, by I. C. Russell. 1889. 65 p.

*80. Correlation papers: Deveonian and Carboniferous, by H. S. Williams. 1891. 279 p.

*81. Correlation papers: Cambrian, by C. D. Walcott. 1891. 447 p.

*84. Correlation papers: Neocene, by W. H. Dall and G. D. Harris. 1892. 349 p.

*128. The Bear River formation and its characteristic fauna, by C. A. White. 1895. 108 p.

BULLETINS--Continued

*170. Survey of the boundary line between Idaho and Montana from the international boundary to the crest of the Bitterroot Mountains, by R. U. Goode. 1900. 67 p.

*174. Survey of the northwestern boundary of the United States, 1857-1861, by Marcus Baker. 1900. 78 p.

*199. Geology and water resources of the Snake River Plains of Idaho, by I. C. Russell. 1902. 192 p.

*213. Contributions to economic geology, 1902. 1903. 449 p. Contains: Mineral deposits of the Bitterroot Range and Clearwater Mountains, Mont., by Waldemar Lindgren. p. 66-70.

*217. Notes on the geology of southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 83 p.

*258. The origin of certain place names in the United States, by Henry Gannett. 1905. 334 p.

*260. Contributions to economic geology, 1904. 1905. Contains: The production of gold in the United States in 1904, by Waldemar Lindgren. p. 32-38; The production of silver in the United States in 1904, by Waldemar Lindgren. p. 39-44; Ore deposits of the Coeur d'Alene district, Idaho, by F. L. Ransome. p. 274-303.

*269. Corundum and its occurrence and distribution in the United States, by J. H. Pratt. 1906. 175 p.

*285. Contributions to economic geology, 1905. 1906. Contains: Economic features of northern Idaho and northwestern Montana, by D. F. MacDonald. p. 41-52; Ore deposits in the St. Joe River basin, Idaho, by A. J. Collier. p. 129-139.

*315. Contributions to economic geology, 1906—Part 1. 1907. Contains: Gold developments in central Uinta County, Wyo., and at other points on Snake River, by A. R. Schultz. p. 71-88; Phosphate deposits in Western United States, by F. B. Weeks and W. F. Ferrier. p. 449-462.

*340. Contributions to economic geology, 1907—Part 1. 1908. Contains: Notes on the Fort Hall mining district, Idaho, by F. B. Weeks and V. C. Heikes. p. 175-183.

*360. Pre-Cambrian geology of North America, by C. R. Van Hise and C. K. Leith. 1909. 939 p.

*384. A geological reconnaissance in northern Idaho and northwestern Montana, by F. C. Calkins, with notes on the economic geology, by D. F. MacDonald. 1909. 112 p.

*430. Contributions to economic geology, 1909, Part 1. 1910. Contains: Geology of the copper deposits near Montpelier, Bear Lake County, Idaho, by H. S. Gale. p. 112-121; An occurrence of monazite in northern Idaho, by F. C. Schrader. p. 184-191; Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah, by H. S. Gale and R. W. Richards. p. 457-535; The salt resources of the Idaho-Wyoming border, with notes on the geology, by C. L. Breger. p. 555-569.

*431. Contributions to economic geology, 1909—Part 2. 1911. Contains: Gas and oil prospects near Vale, Oreg., and Payette, Idaho, by C. W. Washburne. p. 26-55.

*436. The fauna of the phosphate beds of the Park City formation in Idaho, Wyoming, and Utah, by G. H. Girty. 1910. 82 p.

*466. Retracement of the boundary line between Idaho and Washington from the junction of Snake and Clearwater Rivers northward to the international boundary. 1911. 39 p.

BULLETINS--Continued

*470. Contributions to economic geology, 1910—Part 1. 1911. Contains: Geology and mineralization of the upper St. Joe River basin, Idaho, by J. T. Pardee. p. 39-61; Gold-bearing ground moraine in northwestern Montana, by F. C. Schrader. p. 62-74; Geologic relation of ore deposits in the Elkhorn Mountains, Mont., by R. W. Stone. p. 75-89; Notes on lead and copper deposits in the Bear River Range, Idaho and Utah, by R. W. Richards. p. 177-187; Preliminary report on a portion of the Idaho phosphate reserve, by R. W. Richards and G. R. Mansfield. p. 371-439; Sulphur deposits near Soda Springs, Idaho, by R. W. Richards and J. H. Bridges. p. 499-503; The types, modes of occurrence, and important deposits of asbestos in the United States, by J. S. Diller. p. 505-524.

*487. Results of spirit leveling in Idaho, 1986 to 1919, inclusive. 1911. 46 p. (See Bulletin 567.)

*507. The mining districts of the Western United States, by J. M. Hill. 1912. 309 p.

*522. Portland cement materials and industry in the United States, by E. C. Eckel, with contributions by E. F. Burchard and others. 1913. 401 p.

*523. Nitrate deposits, by H. S. Gale. 1912. 36 p. (See also Bulletin 838.)

*528. Geology and ore deposits of Lemhi County, Idaho, by J. B. Umpleby. 1913. 182 p.

*530. Contributions to economic geology, 1911—Part 1. 1913. Contains: A preliminary account of the ore deposits of the Loon Creek district, Idaho, by J. B. Umpleby. p. 66-74; Geology of the St. Joe-Clearwater region, Idaho, by F. C. Calkins and E. L. Jones, Jr. p. 75-86; A geologic reconnaissance in southeastern Idaho, by A. R. Schultz and R. W. Richards. p. 267-284; Mica in Idaho, New Mexico, and Colorado, by D. B. Sterrett. p. 375-390.

*531. Contributions to economic geology, 1911—Part 2. 1913. Contains: Coal at Horseshoe Bend and Jerusalem Valley, Boise County, Idaho, by C. F. Bowen. p. 245-251; Lignite in the Goose Creek district, Cassia County, Idaho, by C. F. Bowen. p. 252-262; Miscellaneous analyses of coal samples from various fields of the United States. p. 331-355.

*539. Some ore deposits in northwestern Custer County, Idaho, by J. B. Umpleby. 1913. 104 p.

*540. Contributions to economic geology, 1912—Part 1. 1914. Contains: Economic geology of the region around Mullan, Idaho, and Saltese, Mont., by F. C. Calkins and E. L. Jones, Jr. p. 167-211; The lead-silver deposits of the Dome district, Idaho, by J. B. Umpleby. p. 212-222.

*541. Contributions to economic geology, 1912—Part 2. 1914. Contains: The Horseshoe Creek district of the Teton Basin coal field, Fremont County, Idaho, by E. G. Woodruff. p. 379-388; and Analyses of coal samples from various fields of the United States, by M. R. Campbell. p. 491-526.

*567. Results of spirit leveling in Idaho, 1896-1914, inclusive. 1915. 130 p.

*577. Geology of the phosphate deposits northeast of Georgetown, Idaho, by R. W. Richards and G. R. Mansfield. 1914. 76 p.

*580. Contributions to economic geology, 1913—Part 1. 1915. Contains: Ore deposits in the Sawtooth quadrangle, Blaine and Custer Counties, Idaho, by J. B. Umpleby. p. 221-249.

*585. Useful minerals of the United States, compiled by Samuel Sanford and R. W. Stone. 1914. 250 p. (See also Bulletin 624.)

*599. Our mineral reserves—How to make America industrially independent, by G. O. Smith. 1914. 48 p.

BULLETINS--Continued

*611. Guidebook of the Western United States—Part A, The Northern Pacific Route, with a side trip to Yellowstone Park, by M. R. Campbell and others. 1915. 218 p.

*612. Guidebook of the Western United States—Part B, The Overland Route, with a side trip to Yellowstone Park, by W. T. Lee and others. 1915. 244 p.

*620. Contributions to economic geology, 1915—Part 1. 1916. Contains: Nitrate deposits in southern Idaho and eastern Oregon, by G. R. Mansfield. p. 19-44; Notes on the fine gold of Snake River, Idaho, by J. M. Hill. p. 271-294.

*621. Contributions to economic geology, 1915—Part 2. 1916. Contains: The Orofino coal field, Clearwater, Lewis, and Idaho Counties, Idaho, by C. T. Lupton. p. 99-108.

*624. Useful minerals of the United States, compiled by F. C. Schrader, R. W. Stone, and Samuel Sanford. 1916. 412 p.

*625. The enrichment of ore deposits, by W. H. Emmons. 1917. 530 p.

*640. Contributions to economic geology, 1916—Part 1. 1917. Contains: Lode mining in the Quartzburg and Grimes Pass porphyry belt, Boise Basin, Idaho, by E. L. Jones, Jr. p. 83-111.

*652. Tungsten minerals and deposits, by F. L. Hess. 1917. 85 p. (See Map MR-25.)

*669. Salt resources of the United States, by W. C. Phalen. 1919. 284 p.

*680. A geologic reconnaissance for phosphate and coal in southeastern Idaho and western Wyoming, by A. R. Schultz. 1918. 84 p.

*697. Gypsum deposits of the United States, by R. W. Stone and others. 1920. 326 p. (See Map MR-33.)

*708. High-grade clays of the Eastern United States, with notes on some western clays, by H. Ries, W. S. Bayley, and others. 1922. 314 p.

*710. Contributions to economic geology, 1919—Part 1. 1920. Contains: A reconnaissance of the Pine Creek district, Idaho, by E. L. Jones, Jr. p. 1-36.

*711. Contributions to economic geology, 1919—Part 2. 1920. Contains: Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah, by D. D. Condit. p. 15-40.

*713. Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho, by G. R. Mansfield, with a chapter on water resources, by W. B. Heroy. 1920. 152 p.

*715. Contributions to economic geology, 1920—Part 1. 1921. Contains: Geology of the Yellow Pine cinnabar-mining district, Idaho, by E. S. Larsen and D. C. Livingston. p. 73-83.

*716. Contributions to economic geology, 1920—Part 2. 1921. Contains: Coal in eastern Idaho, by G. R. Mansfield. p. 123-153.

*717. Sodium sulphate, its sources and uses, by R. C. Wells. 1923. 43 p.

*729. Oil shale of the Rocky Mountain region, by D. E. Winchester. 1923. 204 p.

*732. Geology and ore deposits of Shoshone County, Idaho, by J. B. Umpleby and E. L. Jones, Jr. 1923. 156 p.

*740. Mica deposits of the United States, by D. B. Sterrett. 1923. 342 p.

*750-F. Molybdenite in the Rocky Bar district, Idaho, by F. D. Schrader. 1925. p. 87-99.

*761. Molybdenum deposits—A short review, by F. L. Hess. 1924. 35 p.

*774. The copper deposits near Salmon, Idaho, by C. P. Ross. 1925. 44 p.

*780. Contributions to economic geology, 1925—Part 1. 1926. Contains: Antimony and quicksilver deposits in the Yellow Pine district, Idaho, by F. C. Schrader and C. P. Ross. p. 137-167.

BULLETINS--Continued

*795. Contributions to economic geology, 1927—Part 1. 1928. Contains: Phosphate rock in the Three Forks-Yellowstone Park region, Mont., by D. D. Condit and others. p. 147-209; A manganese deposit of Pleistocene age in Bannock County, Idaho, by D. F. Hewett. p. 211-221.

*803. Geography, geology, and mineral resources of the Portneuf quadrangle, Idaho, by G. R. Mansfield. 1929. 110 p.

*811. Contributions to economic geology, 1929—Part 1. 1930. Contains: Volcanic tuffs and sandstones used as building stones in the upper Salmon River Valley, Idaho, by C. H. Behre, Jr. 1930. p. 237-252.

*814. Geology and ore deposits of the Wood River region, Idaho, by J. B. Umpleby, L. G. Westgate, and C. P. Ross, with a description of Minnie Moore and nearby mines, by D. F. Hewett. 1930. 250 p.

*821-A. A graphic history of metal mining in Idaho, by C. P. Ross. 1931. p. 1-9.

*838. Nitrate deposits of the United States, by G. R. Mansfield and Leona Boardman. 1932. 107 p.

*846-D. Some lode deposits in the northwestern part of the Boise Basin, Idaho, by C. P. Ross. 1934. p. 239-285.

*854. Geology and ore deposits of the Casto quadrangle, Idaho, by C. P. Ross. 1934 (1935). 135 p.

*877. Geology and ore deposits of the Bayhorse region, Custer County, Idaho, by C. P. Ross. 1938. 161 p.

*896. Lexicon of geologic names of the United States (including Alaska), by M. G. Wilmarth. 1938. Part 1, A—L, p. 1-1244; Part 2, M—Z, p. 1245-2396. (See Bulletins 1200 and 1350.)

*922-I. Antimony deposits of a part of the Yellow Pine district, Valley County, Idaho—A preliminary report, by D. E. White. 1940. p. 247-279.

*931-A. Tungsten resources of the Blue Wing district, Lemhi County, Idaho, by Eugene Callaghan and D. M. Lemmon. 1941. p. 1-21.

*944-A. Phosphate deposits of the Teton Basin area, Idaho and Wyoming, by L. S. Gardner. 1914. p. 1-36.

*944-B. Geology of the lead-silver deposits of the Clark Fork district, Bonner County, Idaho, by A. L. Anderson. 1947. p. 37-117.

*944-C. Geology and ore deposits of Boise Basin, Idaho, by A. L. Anderson. 1947 (1949). p. 119-319. Includes title page, contents, and list of illustrations for volume.

*955-C. Phosphate deposits of the Deer Creek-Wells Canyon area, Caribou County, Idaho, by Charles Deiss. 1949 (1950). p. 61-101.

969-F. Geology of the tungsten, antimony, and gold deposits near Stibnite, Idaho, by J. R. Cooper. 1951. p. 151-197. $2.50.

*982-A. Phosphatic rocks in the Deer Creek-Wells Canyon area, Idaho, by W. R. Lowell. 1952. p. 1-52.

*982-E. Iron ore deposits of the Iron Mountain district, Washington County, Idaho, by J. H. Mackin. 1953. p. 121-151.

*988-D. Distribution of uranium in rich phosphate beds of the Phosphoria formation, by M. E. Thompson. 1953. p. 45-67.

*988-H. Uranium and thorium deposits in east-central Idaho and southwestern Montana, by A. F. Trites, Jr., and E. W. Tooker. 1953. p. 157-209.

*1009-D. Further studies of the distribution of uranium in rich phosphate beds of the Phosphoria formation, by M. E. Thompson. 1954. p. 107-123.

*1015-A. Flourspar deposits near Meyers Cove, Lemhi County, Idaho, by D. C. Cox. 1954. p. 1-21.

*1015-I. Geology of the Dry Valley quadrangle, Idaho, by E. R. Cressman and R. A. Gulbrandsen. 1955. p. 257-270.

BULLETINS--Continued

1019-E. Magnesium resources of the United States—A geologic summary and annotated bibliography to 1953, by R. E. Davis. 1957. p. 373-515. 70c.

*1021-F. Ordovician and Silurian coral faunas of Western United States, by Helen Duncan. 1956. p. 209-236.

*1027-P. Geology of the Murray area, Shoshone County, Idaho, by J. W. Hosterman. 1956. p. 725-748.

1030-H. Uranium in black shale deposits, northern Rocky Mountains and Great Plains, by W. J. Mapel. 1956. p. 211-235. 55c.

*1042-A. Geology of the Johnson Creek quadrangle, Caribou County, Idaho, by R. A. Gulbrandsen, K. P. McLaughlin, F. S. Honkala, and S. E. Clabaugh. 1956. p. 1-23.

*1042-D. Quicksilver deposits near Weiser, Washington County, Idaho, by C. P. Ross. 1956 (1957). p. 79-104.

1042-E. Physical stratigraphy of the Phosphoria formation in northwestern Wyoming, by R. P. Sheldon. 1957. p. 105-185. $1.25.

1042-G. Gem stones of the United States, by D. M. Schlegel. 1957. p. 203-253. (Reprint.) 35c.

1042-K. Dismal Swamp placer deposit, Elmore County, Idaho, by F. C. Armstrong. 1957. p. 383-392. 15c.

1046-C. Uranium-bearing minerals in placer deposits of the Red River valley, Idaho County, Idaho, by F. C. Armstrong and P. L. Weis. 1957. p. 25-36. 30c.

*1055. Uranium in coal in the Western United States. 1959 (1960). 315 p. (Contains: Tertiary geology of the Goose Creek district, Cassia County, Idaho, Box Elder County, Utah, and Elko County, Nev., by W. J. Mapel and W. J. Hail, Jr. p. 217-254; Geology and uranium deposits in carbonaceous rocks of the Fall Creek area, Bonneville County, Idaho, by J. D. Vine. p. 255-294.)

*1070-A. A reconnaissance of the Idaho batholith and comparison with the southern California batholith, by E. S. Larsen, Jr., and R. G. Schmidt. 1958. p. 1-83.

*1070-B. Lead-alpha ages of the Mesozoic batholiths of western North America, by E. S. Larsen, Jr., David Gottfried, H. W. Jaffe, and C. L. Waring. 1958. p. 35-62.

*1070-C. Distribution of uranium in rocks and minerals of the Mesozoic batholiths in Western United States, by E. S. Larsen, Jr., and David Gottfried. 1961. p. 63-103. Title page and contents for volume available free on application to the Geological Survey.

*1072-B. Barite resources of the United States, by D. A. Brobst. 1958. p. 67-130. (The volume title given in the publication is incorrect.) (See Map MR-43.)

*1074-B. Reconnaissance for radioactive minerals in Washington, Idaho, and western Montana, 1952-1955, by P. L. Weis, F. C. Armstrong, and Samuel Rosenblum. 1958 (1959). p. 7-48.

1080. Review and annotated bibliography of ancient lake deposits (Precambrian to Pleistocene) in the Western United States, by J. H. Feth. 1964. 119 p. $2.50.

*1081-F. Geology of the southern part of the Lemhi Range, Idaho, by C. P. Ross. 1961. p. 189-260.

*1082-C. Iron-ore resources of the United States including Alaska and Puerto Rico, 1955, by M. S. Carr and C. E. Dutton. 1959. p. 61-134. (See also Map MR-51.)

1083-E. Anomalous remanent magnetization of basalt, by Allan Cox. 1960 (1961). p. 131-160.

BULLETINS--Continued

*1084-C. Selenium content of some volcanic rocks from Western United States and Hawaiian Islands, by D. F. Davidson and H. A. Powers. 1959. p. 69-81.

1091. Investigations of some clay deposits in Washington and Idaho, by J. H. Hosterman, V. E. Scheid, V. T. Allen, and I. G. Sohn. 1960 (1961). 147 p. $2.75.

*1097-A. Evaluation of the lead-alpha (Larsen) method for determining ages of igneous rocks, by David Gottfried, H. W. Jaffe, and F. E. Senftle. 1959. p. 1-63.

1097-B. Lead-alpha age determination of accessory minerals of igneous rocks (1953-1957), by H. W. Jaffe, David Gottfried, C. L. Waring, and H. W. Worthing. 1959. p. 65-148. 30c. Title page and contents for volume available free on application to the Geological Survey.

*1098-A. Geochemical studies in the Coeur d'Alene district, Shoshone County, Idaho, by V. C. Kennedy, with a section on Geology, by S. W. Hobbs. 1960 (1961). p. 1-55. (See also Professional Paper 478.)

*1112-A. Selenium in some epithermal deposits of antimony, mercury, and silver and gold, by D. F. Davidson. 1960. p. 1-15.

*1121-G. Geology of the American Falls quadrangle, Idaho, by W. J. Carr and D. E. Trimble. 1963. p. G1-G44.

*1126. Geology and thorium-bearing deposits of the Lemhi Pass area, Lemhi County, Idaho, and Beaverhead County, Mont., by W. N. Sharp and W. S. Cavender. 1962 (1963). 76 p.

*1133-E. Subsurface geology of the National Reactor Testing Station, Idaho, by E. H. Walker. 1964. p. E1-E52.

1134. Ordovician graptolites of the Basin Ranges in California, Nevada, Utah, and Idaho, by R. J. Ross, Jr., and W. B. N. Berry. 1963. 177 p. $1.75.

*1135-A. Oxidized zinc deposits of the United States—Part 1, General Geology, by A. V. Heyl and C. N. Bozion. 1962. p. A1-A49.

*1136. Coal reserves of the United States—A progress report, January 1, 1960, by Paul Averitt. 1961. 116 p. (Superseded by Bulletin 1275.)

*1141-K. Geology of the Clark Fork quadrangle, Idaho-Montana, by J. E. Harrison and D. A. Jobin. 1963. p. K1-K38.

*1141-L. Columbia River basalt in the Riggins quadrangle, western Idaho, by Warren Hamilton. 1963. p. L1-L37.

*1141-M. Geology of the Jarbidge quadrangle, Nevada-Idaho, by R. R. Coats. 1964. p. M1-M24.

*1142-A. Geology and mineral deposits of the Twin Crags quadrangle, Idaho, by A. B. Campbell and S. E. Good. 1963. p. A1-A33.

1148. Summary of rock salt deposits in the United States as possible storage sites for radioactive waste materials, by W. G. Pierce and E. I. Rich. 1962. 91 p. $1.25.

*1153. Geology of the Georgetown Canyon-Snowdrift Mountain area, southeastern Idaho, by E. R. Cressman. 1964. 105 p.

*1167. Talc resources of the United States, by A. H. Chidester, A. E. J. Engel, and L. A. Wright. 1964. 61 p.

*1181-F. Minor elements in bedrock soil and vegetation at an outcrop of the Phosphoria Formation on Snowdrift Mountain, southeastern Idaho, by F. B. Lotspeich and E. L. Markward. 1963. p. F1-F42.

*1181-G. Reconnaissance petrographic cross section of the Idaho batholith in Adams and Valley Counties, Idaho, by D. L. Schmidt. 1964. p. G1-G50.

*1182-E. Investigations of molybdenum deposits in the conterminous United States, 1942-1960, by Harold Kirkemo, C. A. Anderson, and S. C. Creasey, with sections by numerous authors. 1965. p. E1-E90.

BULLETINS--Continued

*1200. Lexicon of geologic names of the United States for 1936-1960, by G. C. Keroher and others. 1966. Part 1, A—F (v. 1, p. 1-1448); Part 2, G—O (v. 2, p. 1449-2886); Part 3, P—Z (v. 3, p. 2887-4341). (See Bulletin 1350.)

*1205. Geology of the Garns Mountain quadrangle, Bonneville, Madison, and Teton Counties, Idaho, by M. H. Staatz and H. F. Albee. 1966. 122 p.

1217. Geology of the Stewart Flat quadrangle, Caribou County, Idaho, by K. M. Montgomery and T. M. Cheney. 1967. 63 p. $1.25.

1223. Nickel deposits of North America, by H. R. Cornwall. 1966. 62 p. 25c.

*1224-G. The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier. 1966. p. G1-G15.

1252-A. Geology of part of the Alder Creek mining district, Custer County, Idaho, by W. H. Nelson and C. P. Ross. 1968. $1.

1254-J. The Kinnikinic Quartzite of central Idaho—Redefinition and subdivision, by S. W. Hobbs, W. H. Hays, and R. J. Ross, Jr. 1968. p. J1-J22. 15c.

1275. Coal resources of the United States, January 1, 1967, by Paul Averitt. 1969. 116 p. 65c.

1311-A. Quaternary geology of Long and Bear Valleys, west-central Idaho, by D. L. Schmidt and J. H. Mackin. 1970. p. A1-A22. $1.

1312-O. Mineralogy and geochemistry of some Belt rocks, Montana and Idaho, by J. E. Harrison and D. J. Grimes. 1970. p. O1-O49. 35c.

1319-D. Mineral resources of the Sawtooth Primitive Area, Idaho, by T. H. Kiilsgaard, V. L. Freeman, and J. S. Coffman. 1970. p. D1-D174. $1.75.

1350. Lexicon of geologic names of the United States for 1961-1967, by G. C. Keroher. 1970. 848 p. $3.50.

WATER-SUPPLY PAPERS

*5. Irrigation practice on the Great Plains, by E. B. Cowgill. 1897. 39 p.

*23. Water-right problems of the Bighorn Mountains, by Elwood Meade. 1899. 62 p.

*44. Profiles of rivers in the United States, by Henry Gannett. 1901. 100 p.

*53. Geology and water resources of Nez Perce County, Idaho—Part 1, by I. C. Russell. 1901. p. 1-85.

*54. Geology and water resources of Nez Perce County, Idaho—Part 2, by I. C. Russell. 1901. p. 87-141.

*78. Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon, by I. C. Russell. 1903. 53 p.

*93. Proceedings of first conference of engineers of the Reclamation Service, with accompanying papers. 1904. 361 p.

*149. Preliminary list of deep borings in the United States, by N. H. Darton. 1905. 175 p.

*274. Some stream waters of the Western United States, with chapters on Sediment carried by the Rio Grande and the industrial application of water analyses, by Herman Stabler. 1911. 188 p.

*337. The effects of ice on stream flow, by W. G. Hoyt. 1913. 77 p.

*340. Stream-gaging stations and publications relating to water resources, 1885-1913, by B. D. Wood. 1916. 195 p.

*346. Profile surveys in the basin of Clark Fork of Columbia River, Mont.-Idaho-Wash. 1914. 6 p.

*347. Profile surveys in Snake River Basin, Idaho. 1914. 12 p.

*350. Profile surveys in Bear River Basin, Idaho. 1914. 7 p.

*420. Profile surveys along Henrys Fork, Idaho, and Logan River and Blacksmith Fork, Utah. 1916. 8 p.

WATER-SUPPLY PAPERS--Continued

*491. Water supply of St. Mary and Milk Rivers, 1898-1917, by B. E. Jones and R. J. Burley. 1920. 590 p.

*500. Contributions to the hydrology of the United States, 1921. Contains Coeur d'Alene Lake, Idaho, and the overflow lands, by R. W. Davenport. 1922. p. 1-31; Some characteristics of runoff in the Rocky Mountain region, by Robert Follansbee. 1922. p. 55-74.

*517. Water powers of the Great Salt Lake basin, by R. R. Woolley, with an introduction by N. C. Grover. 1924. 270 p.

*520. Contributions of the hydrology of the United States, 1923-24. 1925. 129 p. Contains: Power resources of the Snake River between Huntington, Oreg., and Lewiston, Idaho, by W. G. Hoyt. p. 27-51; Temperature of water available for industrial use in the United States, by W. D. Collins. p. 97-104.

*539. Geology and ground-water resources of Townsend Valley, Mont., by J. T. Pardee. 1925. 61 p.

*557. Large springs in the United States, by O. E. Meinzer. 1927. 94 p.

*558. Preliminary index to river surveys made by the United States Geological Survey and other agencies, by B. E. Jones and R. O. Helland. 1926. 108 p. (See also Water-Supply Paper 995.)

*560. Contributions to the hydrology of the United States, 1925. 1926. Contains: Chemical character of ground waters of the northern Great Plains, by H. B. Riffenburg. p. 31-52; Preliminary report on the geology and water resources of the Mud Lake basin, by H. T. Stearns and L. L. Bryan. p. 87-134.

*657. Water utilization in the Snake River basin, by W. G. Hoyt, with a preface by Herman Stabler. 1935. 379 p.

*658. The industrial utility of public water supplies in the United States, 1932, by W. D. Collins, W. L. Lamar, and E. W. Lohr. 1934. 135 p. (See Water-Supply Paper 1300.).

*659. Contributions to the hydrology of the United States, 1932. 1932. Contains: Index of analyses of natural waters in the United States, 1926 to 1931, by W. D. Collins and C. S. Howard. p. 191-209.

*679-B. Thermal springs in the United States, by N. D. Stearns, H. T. Stearns, and G. A. Waring. 1937. p. 59-206. (See Professional Paper 492.)

*771. Floods in the United States—Magnitude and frequency, by C. S. Jarvis and others. 1936. 497 p.

*774. Geology and ground-water resources of the Snake River Plain in southeastern Idaho, by H. T. Stearns, Lynn Crandall, and W. G. Steward. 1938 (1939). 268 p.

*775. Records of wells on the Snake River Plain, southeastern Idaho, by H. T. Stearns, Lynn Crandall, and W. G. Steward. 1936. 139 p.

*818. Geology and water resources of the Mud Lake region, Idaho, including the Island Park area, by H. T. Stearns, L. L. Bryan, and Lynn Crandall. 1939. 125 p.

*820. Drought of 1936, with discussion on the significance of drought in relation to climate, by J. C. Hoyt. 1938. 62 p.

*847. Maximum discharges at stream-measurement stations through December 31, 1937, by G. R. Williams and L. C. Crawford, with a supplement including additions and changes through September 30, 1938, by W. S. Eisenlohr, Jr. 1940 (1941). 272 p.

*849-B. Effect upon ground-water levels of proposed surface-storage in Flathead Lake, Mont., by R. C. Cady. 1941. p. 59-81.

*866-A. Geology of dam sites on the upper tributaries of the Columbia River—Part 1, Katka, tunnel No. 8, and Kootenai Falls dam sites, Kootenai River, Idaho and Mont., by C. E. Erdmann. 1941. p. 1-36.

WATER-SUPPLY PAPERS--Continued

*889-B. Water-table fluctuations in the Spokane Valley and contiguous area, Washington-Idaho, by A. M. Piper and G. A. LaRocque, Jr. 1944. p. 83-139.

*916. Summary of records of surface waters of upper Columbia River basin in Montana and Idaho, 1898-1938, by A. H. Tuttle and T. R. Newell. 1943. 216 p.

*995. Index to river surveys made by the United States Geological Survey and other agencies, revised to July 1, 1947, by B. E. Jones and R. O. Helland. 1948. 145 p.

1048. Discharge and sediment loads in the Boise River drainage basin, Idaho, 1939-40, by S. K. Love and P. C. Benedict. 1948. 150 p.

1080. Floods of May-June 1948 in Columbia River basin, with a section on Magnitude and frequency of floods, by S. E. Rantz and H. C. Riggs. 1949. 476 p. $1.25.

*1137-I. Summary of floods in the United States during 1950. 1954. p. 957-991.

*1220. Irrigation and streamflow depletion in Columbia River basin above The Dalles, Oreg., by W. D. Simmons. 1953 (1954). 126 p.

*1260-F. Summary of floods in the United States during 1952. 1959. p. 687-713.

*1300. The industrial utility of public water supplies in the United States, 1952—Part 2, States west of the Mississippi River, by E. W. Lohr and S. K. Love. 1954. 462 p.

1314. Compilation of records of surface waters of the United States through September 1950—Part 10, The Great Basin. 1960. 485 p. $2.

*1316. Compilation of records of surface waters of the United States through September 1950—Part 12, Pacific slope basins in Washington and upper Columbia River basin. 1955. 592 p.

*1317. Compilation of records of surface waters of the United States through September 1950—Part 13, Snake River basin. 1956. 566 p.

*1360-A. Reservoirs in the United States, by N. O. Thomas and G. E. Harbeck, Jr. 1956. p. 1-99. (Superseded by Water-Supply Paper 1838.).

*1370-C. Summary of floods in the United States during 1954. 1959. p. 201-263.

*1374. Preliminary survey of the saline-water resources of the United States, by R. A. Krieger, J. L. Hatchett, and J. L. Poole. 1957. 172 p.

1376. Feasibility of ground-water features of the alternate plan for the Mountain Home project, Idaho, by R. L. Nace, S. W. West, and R. W. Mower. 1957. 121 p. $1.75.

1412. Water consumption by water-loving plants in the Malad Valley, Oneida County, Idaho, by R. W. Mower and R. L. Nace. 1957. 33 p. 55c.

*1455-B. Summary of floods in the United States during 1955. 1962. p. 69-143.

*1460-C. Ground-water possibilities south of the Snake River between Twin Falls and Pocatello, Idaho, by E. G. Crosthwaite. 1957 (1958). p. 99-145.

*1460-D. Ground-water geology of the Bruneau-Grand View area, Owyhee County, Idaho, by R. T. Littleton and E. G. Crosthwaite. 1957 (1958). p. 147-198.

1460-H. Ground-water problems in the vicinity of Moscow, Latah County, Idaho, by P. R. Stevens. 1960. p. 325-357. 50c.

*1463. Records of springs in the Snake River valley, Jerome and Gooding Counties, Idaho, 1899-1947, by R. L. Nace, L. S. McQueen, and Arthur Van't Hul. 1958. 62 p.

1473. Study and interpretation of the chemical characteristics of natural water, *second edition*, by J. D. Hem. 1970. 363 p. $2.25. (Revised.)

WATER-SUPPLY PAPERS--Continued

1475-P. Hydrology of stock-water development in southeastern Idaho, by R. F. Hadley. 1962. p. 563-599. 75c.

1478. Ground-water resources of the middle Big Wood River-Silver Creek area, Blaine County, Idaho, by R. O. Smith. 1959. 64 p. $1.75.

1479. Geohydrologic evaluation of streamflow records in the Big Wood River basin, Idaho, by R. O. Smith. 1960. 68 p. $1.

*1496-D. Occurrence and distribution of strontium in natural water, by M. W. Skougstad and C. A. Horr. 1963. p. 55-97.

*1530. Summary of floods in the United States during 1956. 1964. 85 p.

1536-D. The ground-water flow system in the Snake River Plain, Idaho—An idealized analysis, by H. E. Skibitzke and J. A. da Costa. 1962. p. 47-67. 75c.

1539-Q. Reconnaissance of the hydrology of the Little Lost River basin, Idaho, by M. J. Mundorff, H. C. Broom, and Chabot Kilburn. 1963. p. Q1-Q51. 75c.

1576-D. Ground water for irrigation in part of the Fort Hall Indian Reservation, Idaho, by S. W. West and Chabot Kilburn. 1963. p. D1-D33. $1.25.

1585. Effect of irrigation on ground water in southern Canyon County, Idaho, by P. R. Stevens. 1962. 74 p. $1.25.

*1587. Water resources of the Raft River basin, Idaho—Utah, by R. L. Nace and others. 1961. 138 p.

*1609. Ground-water resources of Camas Prairie, Camas and Elmore Counties, Idaho, by W. C. Walton. 1962. 57 p.

*1619-CC. Ground water in the Raft River basin, Idaho, with special significance to irrigation use, 1956-60, by M. J. Mundorff and H. G. Sisco. 1963. p. CC1-CC23.

*1650-A. Floods of December 1955-January 1956 in the Far Western States—Part 1, Description, by Walter Hofmann and S. E. Rantz. 1963. p. A1-A156.

*1650-B. Floods of December 1955-January 1956 in the Far Western States—Part 2, Streamflow data, by Walter Hofmann and S. E. Rantz. 1963. 580 p. Includes title page and contents for volume.

*1652-C. Summary of floods in the United States during 1957. 1963. p. C1-C98.

*1654. Ground water for irrigation in the Snake River basin in Idaho, by M. J. Mundorff, E. G. Crosthwaite, and Chabot Kilburn. 1964. 224 p.

*1660-B. Summary of floods in the United States during 1958. 1963. p. B1-B97.

*1684. Magnitude and frequency of floods in the United States—Part 10, The Great Basin, by E. B. Butler, J. K. Reid, and V. K. Berwick. 1966. 256 p.

*1687. Magnitude and frequency of floods in the United States—Part 12, Pacific slope basins in Washington and upper Columbia River basin, by G. L. Bodhaine and D. M. Thomas. 1964. 337 p.

*1688. Magnitude and frequency of floods in the United States—Part 13, Snake River basin, by C. A. Thomas, H. C. Broom, and J. E. Cummans. 1963 (1964). 250 p.

1734. Compilation of records of surface waters of the United States, October 1950 to September 1960—Part 10, The Great Basin. 1963 (1964). 318 p. $1.75.

*1736. Compilation of records of surface waters of the United States, October 1950 to September 1960—Part 12, Pacific Slope basins in Washington and upper Columbia River basin. 1964. 415 p.

1737. Compilation of records of surface waters of the United States, October 1950 to September 1960—Part 13, Snake River basin. 1963 (1964). 282 p. $1.75.

*1750-B. Summary of floods in the United States during 1959. 1964. p. B1-B101.

1760. Ground-water levels in the United States 1956-60—Northwestern States. 1963. 222 p. $1. (See table.)

WATER-SUPPLY PAPERS--Continued

1779-I. Ground water in the Sandpoint region, Bonner County, Idaho, by E. H. Walker. 1964. p. I1-I29. 60c.

*1779-Q. Ground water in the Midvale and Council areas, upper Weiser River basin, Idaho, by E. H. Walker and H. G. Sisco. 1964. p. Q1-Q26.

1789. Ground water in the upper part of the Teton Valley, Teton Counties, Idaho and Wyoming, by Chabot Kilburn. 1964 (1965). 60 p. 70c.

*1790-B. Summary of floods in the United States during 1960, by J. O. Rostvedt. 1965. p. B1-B147.

1800. The role of ground water in the national water situation, by C. L. McGuinness. 1963. 1121 p. $4.50.

*1810. Summary of floods in the United States during 1961, by J. O. Rostvedt. 1965. 123 p.

*1813. Flood peak runoff and associated precipitation in selected drainage basins in the United States, by Tate Dalrymple. 1965. 406 p.

*1820. Summary of floods in the United States during 1962, by J. O. Rostvedt and others. 1968. 134 p.

1830-B. Summary of floods in the United States during 1963, by J. O. Rostvedt and others. 1968 (1969). p. B1-B120. 60c.

1838. Reservoirs in the United States, by R. O. R. Martin and R. L. Hanson. 1966. 115 p. $1.

1840-C. Summary of floods in the United States during 1964, by J. O. Rostvedt and others. 1970. p. C1-C124. 60c.

*1845. Ground-water levels in the United States, 1961-65—Northwestern States. 1968. 199 p. (See table.)

*1846. Ground water in the vicinity of American Falls Reservoir, Idaho, by M. J. Mundorff. 1967. 58 p.

*1849. Roughness characteristics of natural channels, by H. H. Barnes, Jr. 1967. 213 p.

1866-B. Floods of December 1964 and January 1965 in the Far Western States—Part 2, streamflow and sediment data. 1970 (1971). p. B1-B861. $3.50.

1871. Water data for metropolitan areas, compiled by W. J. Schneider. 1968. 397 p. $1.50.

1879-C. Ground-water aspects of the lower Henrys Fork region, eastern Idaho, by E. G. Crosthwaite, M. J. Nundorff, and E. H. Walker. 1970 (1971). p. C1-C22. 70c.

1879-D. Water resources of the Salmon Falls Creek basin, Idaho-Nevada, by E. G. Crosthwaite. 1969. p. D1-D33. 25c.

1888. Hydrology of the upper Malad River basin, southeastern Idaho, by E. J. Pluhowski. 1970. 89 p. 45c.

1899-C. Sediment transport by streams in the Palouse River basin, Washington and Idaho, July 1961-June 1964, by P. R. Boucher. 1970. p. C1-C37. 70c.

Annual reports of the Geological Survey containing data of the water resources of the United States

Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
Information on the water levels and artesian pressure in observation wells											
1935	*777		1944	*1020		1950	1169	$0.35	1956-60	1760	$1.00
1939	*886		1945	*1027		1951	1195	.55	1961-65	*1845	
1940	*910		1946	*1075		1952	*1225				
1941	*940		1947	1100	$0.45	1953	1269	.65			
1942	*948		1948	1130	.40	1954	1325	.60			
1943	*990		1949	*1160		1955	1408	.60			

Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
Information on the quality of the surface water ("a" indicates data on quality of water for irrigation)											
1947	1102	$1.50	1954	*1353		1959	*1645		1964	1959	$2.00
1948	*1133		(a)	1430	$0.70	(a)	1699	$0.70	(a)	1960	1.00
1949	*1163		1955	1403	1.50	1960	1745	2.00	1965	1966	2.00
1950	*1189		(a)	1465	1.00	(a)	1746	1.25	(a)	1967	1.00
1951	*1200		1956	*1453		1961	1885	2.25			
(a)	*1264		(a)			(a)	1886	1.00			
1952	*1253		1957	*1523		1962	*1945				
(a)	1362		(a)	1524	1.00	(a)	1946	1.00			
1953	*1293		1958	1574	1.75	1963	1951	2.50			
(a)	1380	1.00	(a)	1575	1.00	(a)	1952	1.00			
Stream measurements in the years mentioned											
1897	*16		1921	*530		1935	*790		1949	1150	$0.50
1898	*28			*532			*792			1152	1.00
1899	*38			*533			*793			1153	.60
1900	*51		1922	*550		1936	*810		1950	1180	.50
1902	*85			*552			*812			*1182	
1903	*100			*553			*813			1183	.60
1904	*133		1923	*570		1937	*830		1951	*1214	
	*135			*572			*832			1216	1.00
1905	*176			*573			*833			*1217	
	*178			*590		1938	*860		1952	*1244	
1906	*212			*592			*862			1246	1.25
	*214			*593			*863			1247	1.50
1907-08	*250		1925	*610		1939	*880		1953	*1284	
	*252			*612			*882			*1286	
1909	*270			*613			*883			1287	1.00
	*272		1926	*630		1940	*900		1954	*1344	
1910	*290			*632			*902			*1346	
	*292			*633			*903			*1347	
1911	*310		1927	*650		1941	*930		1955	1394	1.00
	*312			*652			*932			1396	1.25
1912	*330			*653			*933			1397	1.25
	*332		1928	*670		1942	*960		1956	*1444	
1913	*360			*672			*962			1446	1.25
	*362			*673			*963			1447	1.00
1914	*390		1929	*690		1943	*980		1957	1514	1.00
	*392			*692			*982			1516	1.00
	*393			*693			*983			1517	1.00
1915	*410		1930	*705		1944	*1010		1958	*1564	
	*412			*707			*1012			1566	1.25
	*413			*708			*1013			1567	1.00
1916	*440		1931	*720		1945	*1040		1959	*1634	
	*442			*722			*1042			1636	1.50
	*443			*723			*1043			1637	1.00
1917	*460		1932	*735		1946	*1060		1960	1714	1.00
	*462			*737			*1062			*1716	
	*463			*738			*1063			1717	1.00
1918	*480		1933	*750		1947	1090	$0.45	1961-65	1927	4.50
	*482			*752			1092	.75			
	*483			*753			1093	.60			
1919-20	*510		1934	*765		1948	1120	.50			
	*512			*767			1122	1.00			
	*513			*768			1123	.60			

CIRCULARS (Circulars are distributed free upon specific request to the Geological Survey, Washington, D. C. 20242, so long as editions last.)

*9. Geology and ore deposits of the Elk City, Orogrande, Buffalo Hump, and Tenmile districts, Idaho County, Idaho, by P. J. Shenon and J. C. Reed. 1934. 89 p.

*23. Reservoirs in the United States, by G. E. Harbeck, Jr. 1948. 72 p. (Superseded by Water-Supply Papers 1360-A and 1838.)

*36. Annual runoff in Columbia River basin in percent of the mean, 1928-45, by C. C. McDonald and H. C. Riggs. 1948 (1949). 2 p.

*52. Annual runoff in the United States, by W. B. Langbein and others. 1949. 14 p. (See HA-212.)

*56. Preliminary maps and reports released by the Geologic Division, 1946-47, and Conservation Division, 1938-47, compiled by R. A. Atherton, W. H. Eckstein, and R. E. Spratt. 1949. 54 p.

*64. Preliminary maps and reports released by the Geologic Division and the Conservation Division, 1948, compiled by R. A. Atherton, Jane Titcomb, and R. E. Spratt. 1949. 22 p.

*114. The water situation in the United States with special reference to ground water, by C. L. McGuinness. 1951. 138 p., with an appendix of 127 p. (See Water-Supply Paper 1800.)

*115. Estimated use of water in the United States, 1950, by K. A. MacKichan. 1951. 13 p. (See Circulars 398, 456, and 556.)

Open-file report lists for 1949-69 (annual, except as indicated):

Circulars *149 (1949-50), *227 (1951), *263 (1952), *337 (1953), *364 (1954), *379 (1955), *401 (1956), *403 (1957), 412 (1958), 428 (1959), 448 (1960), 463 (1961), 473 (1962), 488 (1963), 498 (1964), 518 (1965), 528 (1966), 548 (1967), 568 (1968), and 618 (1969).

*158 Industrial clays, other than potential sources of alumina of the Columbia Basin, by I. G. Sohn. 1952 (1953). 18 p.

*168. Geochemical studies in the Coeur d'Alene mining district, Idaho, by V. C. Kennedy. 1952. 15 p.

*192. Evaluation of streamflow records in Big Wood River basin, Idaho, by R. P. Jones. 1952. 59 p.

*208. Stratigraphic sections of the Phosphoria formation in Idaho, 1947-48—Part 1, by V. E. McKelvey, D. F. Davidson, F. W. O'Malley, and L. E. Smith. 1953. 49 p.

212. Uranium-bearing coal and carbonaceous rocks in the Fall Creek area, Bonneville County, Idaho, by J. D. Vine and G. W. Moore. 1952. 10 p.

*219. Reconnaissance of uranium and copper deposits in parts of New Mexico, Colorado, Utah, Idaho, and Wyoming, by G. B. Gott and R. L. Erickson. 1952 (1953). 16 p.

262. Stratigraphic sections of the Phosphoria formation in Idaho, 1947-58—Part 3, by F. W. O'Malley, D. F. Davidson, R. A. Hoppin, and R. P. Sheldon. 1953. 43 p.

297. Progress report on investigations of western phosphate deposits, by R. W. Swanson, V. E. McKelvey, and R. P. Sheldon. 1953. 16 p.

*301. Stratigraphic sections of the Phosphoria formation in Idaho, 1947-48-Part 2, by W. E. McKelvey, F. C. Armstrong, R. A. Gulbrandsen, and R. M. Campbell. 58 p.

304. Stratigraphic sections of the Phosphoria formation in Idaho, 1949—Part 1, by R. P. Sheldon, M. A. Warner, M. E. Thompson, and H. W. Peirce. 1953. 30 p.

305. Stratigraphic sections of the Phosphoria formation in Idaho, 1959—Part 2, by D. F. Davidson, R. A. Smart, H. W. Peirce, and J. D. Weiser. 1953. 28 p.

CIRCULARS--Continued

327. Stratigraphic sections of the Phosphoria formation in Idaho, 1950-51, by R. A. Smart, R. G. Waring, T. M. Cheney, and R. P. Sheldon. 1954. 22 p.

371. Ground water in the North Side Pumping Division, Minikoka Project, Minidoka County, Idaho, by E. G. Crosthwaite and R. C. Scott. 1956. 20 p.

*375. Stratigraphic sections of the Phosphoria formation, 1953, by R. W. Swanson, L. D. Carswell, R. P. Sheldon, and T. M. Cheney. 1956. 30 p.

*380. Floods of December 1955-January 1956 in Far Western States; peak discharges. 1956. 15 p. (See Water-Supply Papers 1650-A and 1650-B.)

*390. Index of surface-water records to September 30, 1955—Part 10, The Great Basin, by J. S. Gatewood. 1956. 22 p. (Superseded by Circulars 510 and 580.)

*392. Index of surface-water records to September 30, 1955—Part 12, Pacific slope basins in Washington and upper Columbia River basin, by E. G. Bailey. 1956. 24 p. (Superseded by Circulars 512 and 582.)

*393. Index of surfac-water records to Sepbember 30, 1955—Part 13, Snake River basin, by E. G. Bailey. 1956. 19 p. (Superseded by Circulars 513 and 583.)

398. Estimated use of water in the United States, 1955, by K. A. MacKichan. 1957. 18 p. (See Circulars 456 and 556.)

*409. Water yield and reservoir storage in the United States, by W. B. Langbein. 1959. 5 p.

420. Occurrence of strontium in natural water, by M. W. Skougstadt and C. A. Horr. 1960. 6 p. (See Water-Supply Paper 1496-D.)

436. Preliminary report on ground water in the Salmon Falls area, Twin Falls County, Idaho, by K. H. Fowler. 1960 (1961). 17 p.

445. Occurrence of minor elements in water by W. H. Durum and Joseph Haffty. 1961. 11 p.

456. Estimated use of water in the United States, 1960, by K. A. MacKichan and J. C. Kammerer. 1961 (1962). 44 p. (See Circular 556.)

467. Floods of February 1962 in southern Idaho and northeastern Nevada, by C. A. Thomas and R. D. Lamke. 1962. 30 p.

510. Index of surface-water records to December 31, 1963—Part 10, The Great Basin, by H. P. Eisenhuth. 1965. 35 p. (Superseded by Circulars 580.)

512. Index of surface-water records to December 31, 1963—Part 12, Pacific slope basins in Washington and upper Columbia River basin, by H. P. Eisenhuth. 1965. 39 p. (Superseded by Circular 582.)

513. Index of surface-water records to December 31, 1963—Part 13, Snake River basin, by H. P. Eisenhuth. 1965. 29 p. (Superseded by Circular 583.)

533. Regional trends in water-well drilling in the United States, by Gerald Meyer and G. G. Wyrick. 1966. 8 p.

556. Estimated use of water in the United States, 1965, by C. R. Murray. 1968 (1969). 53 p.

580. Index of surface-water records to September 30, 1967—Part 10, The Great Basin, by H. P. Eisenhuth. 1968. 37 p.

582. Index of surface-water records to September 30, 1967—Part 12, Pacific slopes basins in Washington and upper Columbia River basin, by H. P. Eisenhuth. 1968. 30 p.

583. Index of surface-water records to September 30, 1967—Part 13, Snake River basin, by H. P. Eisenhuth. 1968. 29 p.

MAPS, CHARTS, AND ATLASES

(See ordering instructions on p. 1.)

CORRELATION CHART OF IDAHO. Tentative correlation of named geologic units, by M. G. Wilmarth. 1932. 2 sheets. 10c per set.

CRATERS OF THE MOON NATIONAL MONUMENT, IDAHO. 1957. Lat 43° 19' to 43° 32', long 113° 25' to 113° 37'30". Scale 1:31,680. Contains descriptive text by W. C. Alden. Available in contour and shaded-relief editions. $1 each.

GEOLOGIC MAP INDEX OF IDAHO, by Leona Boardman. Revised by B. L. Smysor. 1959. Shows by colored outlines areas in Idaho for which geologic maps have been published and locates many mine maps that show local geology. Text printed on the margin of the sheet gives the scale, date, author, and source of publication of each geologic map. Scale 1:750,000. 60c.

GEOLOGIC MAP OF IDAHO, by C. P. Ross and J. D. Forrester. 1947. Shows distribution of formations. Scale 1:500,000. $2.50. (Also available from State Bureau of Mines and Geology, Moscow, Idaho.)

GEOLOGIC QUADRANGLE MAPS

GQ-375. Geologic map of the Packsaddle Mountain quadrangle, Idaho, by J. E. Harrison and D. A. Jobin. 1965. Lat 48° to 48° 15', long 116° 15' to 116° 30'. Scale 1:62,500. Accompanied by 4-page text. $1.

GQ-464. Geologic map and sections of the Doublespring quadrangle, Custer and Lemhi Counties, Idaho, by W. J. Mapel, W. H. Read, and R. K. Smith. 1965. Lat 44° 15' to 44° 30', long 113° 45' to 114°. Scale 1:62,500. $1.

GQ-733. Geologic map of the Leadore quadrangle, Lemhi County, Idaho, by E. T. Ruppel. 1968. Lat 44° 30' to 44° 45', long 113° 15' to 113° 30'. Scale 1:62,500. Accompanied by 5-page text. $1.

GQ-734. Geologic map of the Greenacres quadrangle, Washington and Idaho, by P. L. Weis. 1968. Lat 47° 30' to 47° 45', long 117° to 117° 15'. Scale 1:62,500. Accompanied by 4-page text. $1.

GEOPHYSICAL INVESTIGATIONS MAPS

GP-446. Natural gamma aeroradioactivity of the National Reactor Testing Station area, Idaho, by R. G. Bates. 1964. Scale 1:250,000. 75c.

GP-490. Aeromagnetic map of part of the Lanes Creek quadrangle, Caribou County, Idaho, by J. L. Meuschke and C. L. Long. 1965. Scale 1:62,500. 50c.

GP-521. Aeromagnetic map of the Pocatello-Soda Springs area, Bannock and Caribou Counties, Idaho, by C. M. Mitchell, F. F. Knowles, and F. A. Petrafeso. 1965. Scale 1:250,000. 50c.

GP-682. Aeromagnetic map of the Libby and Mt. Pend Oreille quadrangles, Lincoln and Sanders Counties, Mont., and Bonner County, Idaho. 1969. Scale 1:62,500. 50c.

GP-685. Aeromagnetic map of the Trout Creek quadrangle, Sanders and Lincoln Counties, Mont., and Shoshone County, Idaho. 1969. Scale: 1:62,500. 50c.

GP-688. Aeromagnetic map of the Kingston, Kellogg, and part of the Fernwood quadrangles, Shoshone, Benewah, and Kootenai Counties, Idaho. 1969. Scale 1:62,500. 50c.

GP-689. Aeromagnetic map of part of the Avery quadrangle, Shoshone County, Idaho, and Mineral and Sanders Counties, Mont. 1969. Scale 1:62,500. 50c.

GP-690. Aeromagnetic map of the Haugan and St. Regis quadrangles and parts of the Simmons Peak and Illinois Peak quadrangles, Shoshone County, and Mineral and Sanders Counties, Mont. 1969. Scale 1:62,500. 50c.

HYDROLOGIC INVESTIGATIONS ATLASES

HA-61. Stream composition of the conterminous United States, by F. H. Rainwater. 1962. 3 sheets. $1.50 per set.

HA-189. Calcium, sodium, sulfate, and chloride in stream water of the western conterminous United States to 1957, by J. H. Feth. 1965. Scale 1:2,500,000. 4 sheets. $1.50 per set.

HA-194. Generalized map showing annual runoff and productive aquifers in the conterminous United States, compiled by C. L. McGuinness. 1964. Scale 1:5,000,000. 75c.

HA-199. Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids, by J. H. Feth and others. 1965. Scale 1:3,168,000. 2 sheets. Accompanied by 31-page text. $1.25 per set.

HA-200. Chemical quality of public water supplies of the United States and Puerto Rico, 1962, shown as Statewide averages, mainly in graphic and tabular form, by C. N. Durfor and Edith Becker. 1964. 50c.

HA-212. Annual runoff in the conterminous United States, by M. W. Busby. 1966. Scale 1:7,500,000. 75c.

HA-235. Temperature of surface waters in the conterminous United States, by J. F. Blakey. 1966. Scale 1:5,000,000. 3 sheets. Accompanied by 8-page text. 1.25 per set.

*INTERPRETING GEOLOGIC MAPS FOR ENGINEERING PURPOSES. 1953 (1954). Six maps of the Hollidaysburg, Pa., quadrangle. Scale 1:62,500.

MINERAL INVESTIGATIONS FIELD STUDIES MAPS

MF-41. Preliminary geologic map of the Paris-Bloomington vanadium area, Bear Lake County, Idaho, by V. E. McKelvey and J. D. Strobell, Jr. 1955. Scales 1:12,000 and 1:4,800. 4 sheets. 60c per set.

MF-118. Preliminary geologic map of the Snowdrift Mountain quadrangle, Caribou County, Idaho, by E. R. Cressman. 1957. Lat 42° 30' to 42° 37'30", long 111° 07'30" to 111° 15'. Scale 1:24,000. 50c.

MF-120. Uranium deposits and principal ore-bearing formations of the central Cordilleran foreland region, by T. L. Finnell and I. S. Parrish. 1958. 2 sheets; sheet 1 (map), scale 1:750,000. Sheet 2 (table and text). 75c per set. (See Bulletin 1087-I.)

MF-262. Preliminary geologic map of the Garns Mountain SE quadrangle, Bonneville and Teton Counties, Idaho, by M. H. Staatz and H. F. Albee. 1963. Lat 43° 30' to 43° 37'30", long 111° 15' to 111° 22'30". Scale 1:24,000. 50c.

MF-274. Preliminary geologic map of the Garns Mountain NE quadrangle, Teton County, Idaho, by H. F. Albee. 1964. Lat 43° 37'30" to 43° 45', long 111° 15' to 111° 22'30". Scale 1:24,000. 50c.

MF-277. Geology of the Conant Valley quadrangle, Bonneville County, Idaho, by D. A. Jobin and M. L. Schroeder. 1964. Lat 43° 22'30" to 43° 30', long 111° 22'30" to 111° 30'. Scale 1:24,000. 50c.

MF-284. Geologic map of the Thompson Peak quadrangle, Bonneville County, Idaho, by D. A. Jobin and P. E. Soister. 1964. Lat 43° 22'30" to 43° 30', long 111° 07'30" to 111° 15'. Scale 1:24,000. 50c.

MF-287. Geology of the Irwin quadrangle, Bonneville County, Idaho, by D. A. Jobin and M. L. Schroeder. 1964. Lat 43° 22'30" to 43° 30', long 111° 15' to 111° 22'30". Scale 1:24,000. 50c.

MF-299. Preliminary geologic map of the SW¼ of the Bancroft quadrangle, Bannock and Caribou Counties, Idaho, by S. S. Oriel. 1965. Lat 42° 30' to 42° 37'30", long 111° 52'30" to 112°. Scale 1:24,000. 50c.

MINERAL INVESTIGATIONS FIELD STUDIES MAPS--Continued

MF-300. Geologic map of the Driggs quadrangle, Bonneville and Teton Counties, Idaho, and Teton County, Wyo., by E. H. Pampeyan, M. L. Schroeder, E. M. Schell, and E. R. Cressman. 1967. Lat 43° 30' to 43° 45', long 111° to 111° 15'. Scale 1:31,680. 75c.

MINERAL INVESTIGATIONS RESOURCE MAPS

The following maps cover the resources indicated for the United States exclusive of Alaska and Hawaii. All are printed at a scale of 1:3,168,000 and are sold at 75c each, except as indicated.

MR-1. Geologic environment map of alumina resources of the Columbia Basin, by I. G. Sohn. 1952. Scale 1:1,500,000. 80c.

MR-2. The uranium deposits, compiled by R. W. Schnabel. 1955. Scale 1:5,000,000. 50c.

MR-3. Potash occurrences, by M. F. Byrd. 1955. Scale 1:5,000,000. 50c.

MR-13. Copper, by A. R. Kinkle, Jr., and N. P. Peterson. 1962.

MR-15. Lead, by E. T. McKnight, W. L. Newman, and A. V. Heyl. 1962.

MR-16. Vanadium, by R. P. Fischer. 1962.

MR-17. Asbestos, by A. H. Chidester and A. F. Shride. 1962.

MR-18. Pyrophyllite, and kyanite and related minerals, by G. H. Espenshade. 1962.

MR-19. Zinc, by E. T. McKnight, W. L. Newman, and A. V. Heyl. 1962.

MR-20. Antimony, by D. E. White. 1962.

MR-21. Epigenetic uranium deposits, by A. P. Butler, Jr., W. I. Finch, and W. S. Twenhofel. 1962.

MR-22. Bismuth, by J. R. Cooper. 1962.

MR-23. Manganese, by M. D. Crittenden and Louis Pavlides. 1962.

MR-24. Gold, by A. H. Koschmann and M. H. Bergendahl. 1962.

MR-25. Tungsten, by D. M. Lemmon and O. L. Tweto. 1962.

MR-27. Magnesite and brucite, by Benjamin Gildersleeve. 1962.

MR-28. Thorium and rare earths, by J. C. Olson and J. W. Adams. 1962.

MR-29. Titanium, by C. L. Rogers and M. C. Jaster. 1962.

MR-30. Mercury, by E. H. Bailey. 1962.

MR-31. Talc and soapstone, by A. H. Chidester and H. W. Worthington. 1962.

MR-33. Gypsum and anhydrite, by C. F. Withington. 1962.

MR-34. Silver, by E. T. McKnight, W. L. Newman, Harry Klemic, and A. V. Heyl. 1962.

MR-35. Beryllium, by W. R. Griffitts, D. M. Larrabee, and J. J. Norton. 1962.

MR-36. Niobium and tantalum, by R. L. Parker. 1963.

MR-37. High-alumina kaolinitic clay, by Helen Mark. 1963.

MR-43. Barite, by D. A. Brobst. 1965.

MR-44. Tin, by P. L. Killeen and W. L. Newman. 1965.

MR-51. Iron, by M. S. Carr, P. W. Guild, and W. B. Wright. 1967. Accompanied by 20-page text.

MR-55. Molybdenum, by R. U. King. 1970. Accompanied by 20-page text.

MINERAL INVESTIGATIONS (STRATEGIC) MAPS

3-198. Map of Permian phosphate deposits of Montana, Wyoming, Idaho, and Utah, by P. S. Clabaugh. 1946. Scale 1:1,000,000. 30c.

*3-212. Iron-ore deposits of the Western United States, by C. E. Dutton and M. S. Carr. 1947. Scale 1:5,000,000. (See Bulletin 1082-C and Map MR-51.)

MINERAL INVESTIGATIONS (STRATEGIC) MAPS--Continued

Surface geology of the Pine Creek area, Coeur d'Alene region, Shoshone County, Idaho, by V. E. Nelson, J. F. Smith, Jr., G. A. Duell, and R. M. Huchinson. 1945. Scale 1:12,000. 60c.

*Zinc-lead mines of the Pine Creek area, Coeur d'Alene region, Shoshone County, Idaho, by J. D. Forrester. 1944.

Geologic map of the Yellow Pine area, Valley County, Idaho, by D. E. White. 1945. Scale 1:48,000. 20c.

MISCELLANEOUS GEOLOGIC INVESTIGATIONS MAPS

I-332. Geologic map of a part of southwestern Wyoming and adjacent States, by W. H. Bradley. 1961. Scale 1:250,000. 75c.

I-373. Reconnaissance geologic map of west-central Snake River Plain, Idaho, by H. E. Malde, H. A. Powers, and C. H. Marshall. 1963. Scale 1:125,000. 75c.

I-387. Flouride content of ground water in the conterminous United States (maximum reported value for each county), by Michael Fleischer. 1962. Scale 1:5,000,000. 50c.

I-464. Reconnaissance geologic map of the west half of the Spokane quadrangle, Washington and Idaho, by A. B. Griggs. 1966. Lat 47° to 48°, long 117° to 118°. Scale 1:125,000. 50c.

I-557. Geologic map of the Soda Springs quadrangle, southeastern Idaho, by F. C. Armstrong. 1969. Lat 42° 30' to 42° 45', long 111° 30' to 111° 45'. Scale 1:48,000. 2 sheets. $1.50 per set.

I-579. Reconnaissance geologic map of the Riggins quadrangle, west-central Idaho, by Warren Hamilton. 1969. Lat 45° to 45° 30', long 104° to 104° 15'. Scale 1:48,000. $1.

I-580. Geologic map of the Mackay quadrangle, south-central Idaho, by W. H. Nelson and C. P. Ross. 1969 (1970). Lat 43° 30' to 44°, long 113° 30' to 114°. Scale 1:125,000. $1.

I-587. Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho, by R. C. Newcomb. 1970. Lat 44° to 48°, long 116° to 122°. Scale. 1:500,000. $1.

MISCELLANEOUS REPORTS (free upon application to the Geological Survey, Washington, D.C. 20402):

List 1. Press releases, preliminary maps, and preliminary reports released between Jan. 1, 1938, and Jan. 1, 1945.

List 2. Press releases, preliminary maps, and preliminary reports released between Jan. 1, 1945, and Jan. 1, 1946.

REFERENCE LIBRARIES

Many of the publications listed herein may be consulted in the following libraries in Idaho:

BOISE
Boise College Library.
Public.

CALDWELL:
Strahorn Memorial.

MOSCOW:
University of Idaho.

MOSCOW--Continued
Idaho Bureau of Mines and Geology.

POCATELLO:
Idaho State University.

REXBURG:
Ricks College.

GPO 908-578

IDAHO

6

INTRODUCTION AND SUMMARY

(By A. E. Weissenborn, U.S. Geological Survey, Spokane, Wash.)

This report describes the mineral and water resources of Idaho, their occurrence in the State, their uses in industry, and their relative importance to the economy of Idaho. In an introductory section, the mineral industry and its place in the State's economy are briefly discussed. A description of the geology of the State and its influence on the water and mineral resources of the State is also included in this section.

The mineral industry, with a total production of over $3.6 billion and a production in 1962 of $82.6 million, forms an important segment of Idaho's economy. The State's contributions to the national economy have likewise been large. At least 40 different mineral commodities have been produced in the State. Idaho leads the Nation in the production of silver and antimony. In most years, it is first or second among the States in the production of lead and zinc and accounts for a large proportion of the domestic production of cadmium. It has, in time of urgent national need, accounted for as much as 40 percent of the domestic production of tungsten. Its nonmetallic mineral industry has grown greatly in the last few years; in 1962 it produced 1.9 million long tons of phosphate rock, most of which was manufactured into fertilizer to increase the productivity of western farms.

Idaho is generously supplied with water, but there is great variation from area to area. Extremes of annual precipitation range from 60 inches to 8 inches or less, the driest part of the State being the Snake River Plain. Generally speaking, the supply of water exceeds the need in the northern counties, but in the southern part of the State, there are areas of serious shortage. North of the Snake River Plain, most of the streams are perennial, but some streams south of the plain are intermittent. Nearly all the streams draining Idaho flow to the Pacific Ocean through the Columbia River. Because of the seasonal distribution of the flow of many of its streams, reservoir storage is required to maintain adequate supplies of water for irrigation during the growing season.

Ground water is one of the most important renewable resources in Idaho. About 2.6 million acre-feet was withdrawn in 1960 as the sole or principal supply for irrigation of more than 800,000 acres of land, principally in the Snake River Basin. Large amounts are also used for municipal, domestic, industrial, and livestock uses. The Snake River Plain, east of Bliss, and the gravel beneath Rathdrum Prairie, east of Spokane, Wash., are two of the Nation's most productive aquifers. Discharge from the Snake River Plain aquifer near Bliss is 6,000 cubic feet per second; discharge from the Rathdrum Prairie aquifer is about 1,000 cubic feet per second.

More than 3 million acres are irrigated in Idaho, more than 2½ million acres of which are in the Snake River Basin. There remains about 5.8 million acres of unirrigated but otherwise arable lands in the Snake River Basin, much of which could be supplied with water, but technical and legal problems will have to be solved first.

Most of the surface water is suitable for most uses with a minimum of treatment, but contamination from irrigation discharge and industrial and municipal wastes are having a detrimental effect on both surface and ground water.

There are 47 developed waterpower projects having a total installed generating capacity of 1,476 megawatts in Idaho. The State's gross theoretical power capability at developed and undeveloped powersites is 11,149 megawatts. The waterpower potential of the Pend Oreille and Bear Rivers in Idaho is almost fully developed, but the Snake River has the greatest total development. The Salmon River has the greatest waterpower potential of any stream in Idaho but has no powersite developments.

The report has been compiled chiefly by the staffs of the U.S. Geological Survey and the Idaho Bureau of Mines and Geology, but members of the University of Idaho, the Idaho Department of Highways, and the Idaho Department of Reclamation have also contributed. It is based essentially on published information on the geology and resources of Idaho but has been supplemented by material in the files of the U.S. Geological Survey, and the Idaho Bureau of Mines and Geology, and the personal observations of the 37 contributors to the report.

The intention has been to present an objective appraisal of the resources of the State based on the information that is available now. All commodities that occur in significant quantities in the State are discussed, even though they are not now being utilized or are considered to have only slight potential for development. It is realized that new discoveries and developments, and changes in economic condition may significantly alter some of the conclusions that have been reached. Treatment of each commodity is necessarily brief, but comprehensive bibliographies are attached to each major segment of the report for the convenience of those who wish to inquire further into Idaho's mineral and water resources. Throughout the text, specific references are made to these sources of information.

Mr. A. E. Weissenborn assembled the various sections of the report and coordinated the efforts of the individual authors. Dr. R. R. Reid, acting director, Idaho Bureau of Mines and Geology, and Dr. E. F. Cook, formerly director of the Idaho Bureau of Mines and Geology, were most helpful in arranging for participation of the various authors from State agencies.

In acknowledging the efforts of those who have participated in preparation of this report special reference is made to A. L. Anderson and C. P. Ross. A. L. Anderson, formerly professor of geology at the University of Idaho, and for many years a professor at Cornell University, submitted his manuscript sections of this report only a short while before his untimely death. Working in the field during

his summer vacations on behalf of the Idaho Bureau of Mines and Geology, he mapped the geology of an extremely large part of the State. C. P. Ross, now retired after a long and distinguished career with the U.S. Geological Survey, also has mapped and studied the geology of large sections of Idaho. His contributions to our knowledge of the geology of the State have been enormous. These two men have contributed immeasurably to the advancement of knowledge of the geology and mineral resources of the State.

THE MINERAL INDUSTRY IN IDAHO

(By A. E. Weissenborn, U.S. Geological Survey, Spokane, Wash.)

Idaho's mines and quarries have produced more than $2.6 billion of new wealth. Most of this has come from the Coeur d'Alene region, one of the great mining districts of the world, but almost all parts of Idaho have contributed to the more than 40 mineral products whose value makes up this total. With this record, the mineral industry can justly claim an important role in the development of the Gem State from a nearly trackless wilderness little more than 100 years ago to a modern community in which more than 700,000 people live.

The first white men known to have set foot in what is now the State of Idaho were members of the Lewis and Clark Expedition who, in the fall of 1805, crossed the Bitterroot Mountains over the Lolo Trail and descended the Clearwater River. They were followed, and perhaps preceded, by the mountain men and the fur traders. After these, came the missionaries and the westward-bound immigrants in search of new lands. By 1843, hordes of immigrants were beginning to follow the Oregon Trail across the Snake River Plain on their way to the Oregon country, but with few exceptions they merely passed through Idaho. To the mountain man, the trapper, and the immigrant must go the credit of first opening the Idaho country, but it remained for the miner to establish the first permanent settlements, except for a few Mormon farming communities in the southern part of the State (Bolino, 1960). Development of the mineral industry provided the impetus for the establishment of railroads and other means of communication, and provided markets for local agricultural and forest products.

It is not certain when and where metals were first discovered in Idaho. The presence of placer gold in the Boise Basin is reputed to have been known to a Hudson Bay Co. trapper as early as 1844 (Wells, 1964). Ross (1930) reports the discovery of gold on the Pend Oreille River in 1852 by a member of the Stevens Expedition, but Indian hostility prevented exploration. Ricard (1932) also notes that in 1858 members of the Mullan Expedition that surveyed the military road across the Bitterroot Mountains found vein outcrops and some gold, probably in or near what is now the Coeur d'Alene region. These and other less well documented reports indicate that gold and other metals were known in Idaho for some years before mining began, but exploitation of these discoveries was delayed largely because of the hostility of the Indians to miners entering their lands. However, in February 1860, E. D. Pierce discovered placer gold on the North Fork of the Clearwater. In August he returned with a prospecting party to Orofino Creek, and the following winter the town of Pierce was established. The Orofino mining district was organized in January 1861, and Idaho's mineral industry was born (Wells, 1961?, p. 3). By July 1861, 5,000 were were in the area, and prospecting had extended to the South Fork of the Clearwater, where Elk City was founded

(Ricard, 1932, p. 312). In spite of continued Indian hostility, prospecting spread south, and additional discoveries were made in 1861 and 1862 on other tributaries of the Snake, the richest of which were at Florence and Warren. Idaho's major gold rush began in the fall of 1862, when placer discoveries were made at several places in Boise Basin. By 1863, 25,000 miners were in southern Idaho, and mining was being done at Centerville, Pioneerville, Idaho City, Placerville, and other localities. Idaho City alone had a population of over 6,200 and was larger than Portland, Oreg. Prospectors swarmed through the hills, and other discoveries soon followed. Placer gold was found in 1863 in numerous places south of the Middle Fork of the Boise River. Prospecting uncovered gold-bearing lodes at Placerville, Idaho City, Ophir, Bonaparte, Rocky Bar, and other localities. Discoveries were made in the following year south of the Snake River in Owyhee County (Wells, 1964?). By 1869, practically all of the placer areas and many of the gold lode deposits now known in the State had been found. However, the rich placers were exceedingly short lived. The boom days of Pierce and neighboring camps were over after 1864, but in this brief period $20 million worth of gold was produced (Ross, 1930, p. 3). By 1872, the gold rush days in central and south-central Idaho were finished, and mining declined drastically. Placer mining continued for many years at numerous places—and had a marked revival in the depression days of the 1930's—but the bonanza ground was removed in the early years of mining, and since 1911 most of the placer gold has been recovered by dredges.

Miners searching for placers soon found outcropping veins. Early attempts to mine these veins and treat the ore in crude arrastras and stamp mills mostly failed. Mills built in the Silver City area of Owyhee County in 1864 to treat the silver-gold ores were more successful and marked the real beginning of lode mining in Idaho. Later, with improved techniques of mining and milling, gold veins in Boise Basin and elsewhere were worked successfully, but lode gold production, although it lasted much longer, never reached the commanding position once held by placer mining (Ross, 1930, p. 6).

Such were the golden beginnings of Idaho's mineral industry. Dramatic, exciting, though not as lucrative as the gold rush days of California or Montana, these events had an effect on the subsequent history of Idaho far out of proportion to the amount of the gold produced. They brought people and money into the area—Ross (1963a) states that the initial placer activity in Idaho yielded over $30 million—and they provided markets for the farmer who followed the miner. Rudimentary roads replaced the Indian trails; the territory was explored and prospected. Thus, the way was cleared for the permanent settlement of the country and the development of lode mines—first of gold and silver, then later of the more prosaic base metals that now play such an important role in Idaho's economy.

Although some lead had been mined previously as a byproduct of silver mining, base-metal mining did not come into prominence until the development of lead mines in the Wood River area about 1883, and the discovery of the Bunker Hill mine in the Coeur d'Alene area in 1885 (Ross, 1930; Umpleby and others, 1930; Ricard, 1932). Exploitation of these areas marked the beginning of Idaho's mineral industry as we now know it. Growth was spectacularly rapid and, with few

exceptions, the value of mineral production climbed to a peak in 1916 coincident with World War I—a peak which as shown in figure 1 has never been exceeded.

Other periods of high production coincide with the boom of the late 1920's, the defense requirements of World War II and the Korean episode, and assembly of Government stockpiles of strategic minerals during the 1950's. Interspersed with these, were periods of reduced production marked by decreased prices and lessened demand, especially following each war and during the depression of the 1930's. Termination of the stockpile program led to a sharp decline that reached a low point in 1960. Since then, mineral production has again risen with the possibility that a new high will be reached. Note that in figure 1 the value of the minerals produced is expressed in constant dollars, with the 1957–59 dollar taken at 100. This gives a somewhat different curve than if values had been expressed in dollars without correcting for changes in the value of the dollar, but more nearly compares actual amounts of materials produced.

Idaho produces at least 40 different mineral products. These products are important to the local economy, and many of them are essential materials in the national economy. In 1962, Idaho led the Nation in the production of silver and lead and was second in the production of zinc. For most years, it has ranked first or second among the States in the production of these metals. It has accounted for almost the entire domestic output of antimony—formerly from the Yellow Pine mine, now mostly as a byproduct from the silver ores of the Coeur d'Alene district—and accounts for a large proportion of the domestic production of cadmium, also from Coeur d'Alene ores. Idaho also has been a leading producer of tungsten. In the critical war period 1942–44, it accounted for 40 percent of the domestic tungsten production, and from 1948 to 1957 it ranked fifth and sixth among the tungsten-producing States. From 1951 to 1958, it was the chief domestic source of cobalt, and from 1956 to 1959 the placers of Bear Valley in central Idaho supplied almost the entire domestic production of niobium and tantalum.

Idaho is outranked only by Florida and Tennessee in the production of phosphate rock, and by New York in the production of garnet. At times it has been an important producer of mica.

The relative value of many mineral commodities or groups of commodities that have been produced from 1861–1962 is shown in figure 2. Idaho's mineral economy depends heavily on three metals—lead, silver, and zinc—and other mineral commodities except, perhaps, gold, have played a relatively minor role. Of the three major metals, lead and silver have been by far the most important. No zinc was recovered until about 1903, and for many years it was of relatively minor importance, but since 1943 it has at times been equally as important as lead. This is the result of two factors—increasing consumption of zinc and the increasing zinc content of Coeur d'Alene ores relative to lead, in deeper parts of the deposits.

The sources of most of Idaho's metals and the dominance of the Coeur d'Alene district in Idaho's metal production are shown graphically by figure 3. In this chart, the areas of the circles are proportional to the unadjusted dollar value of the production from 28 metalliferous districts in the State. The chart shows only the value of

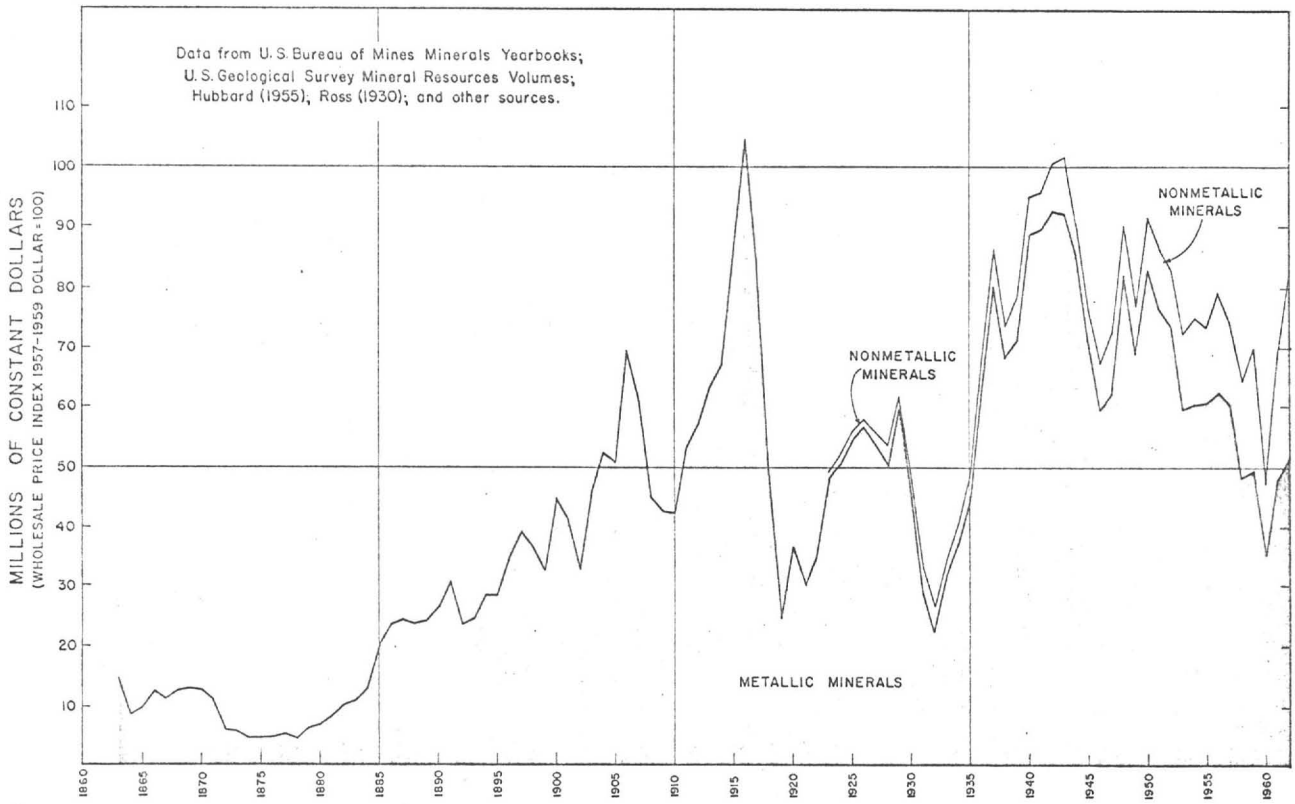

FIGURE 1.—100 years of mineral production from Idaho, 1862–1962.

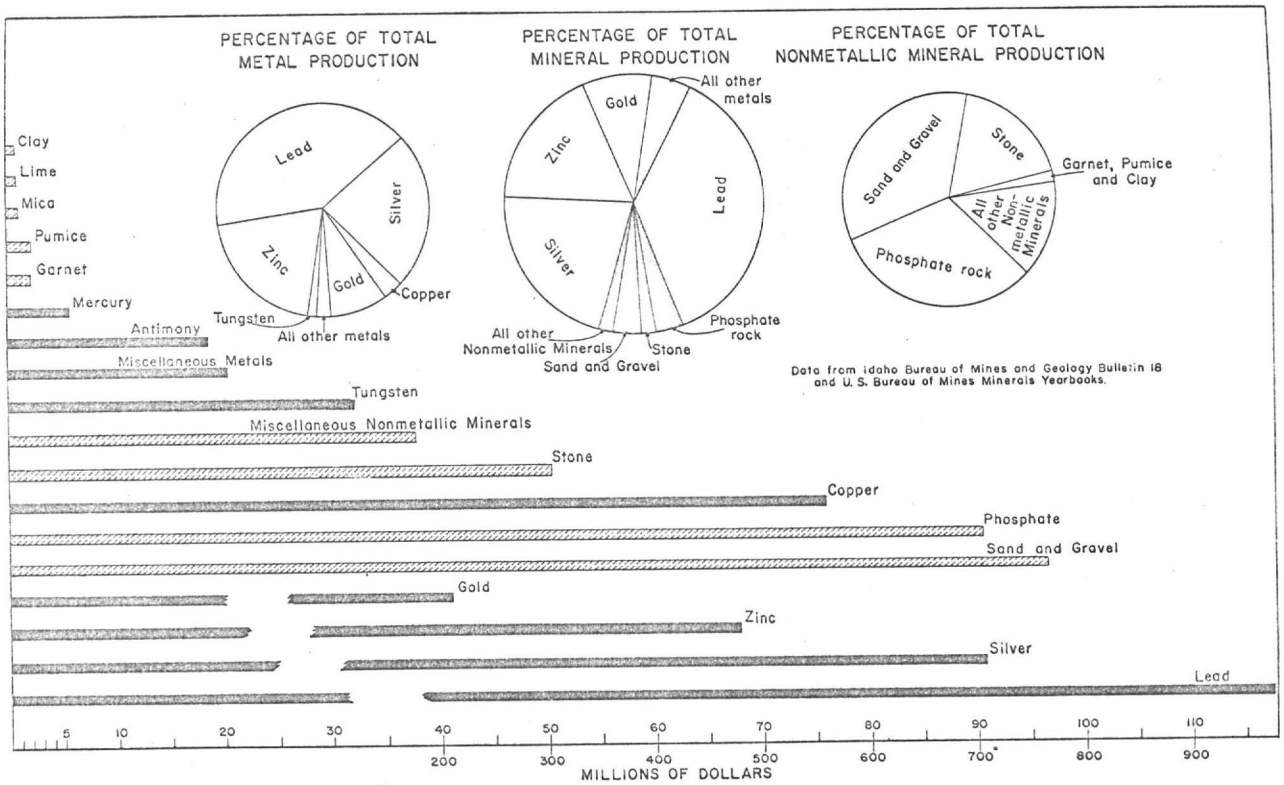

FIGURE 2.—Idaho's mineral production by commodities, 1861–1962.

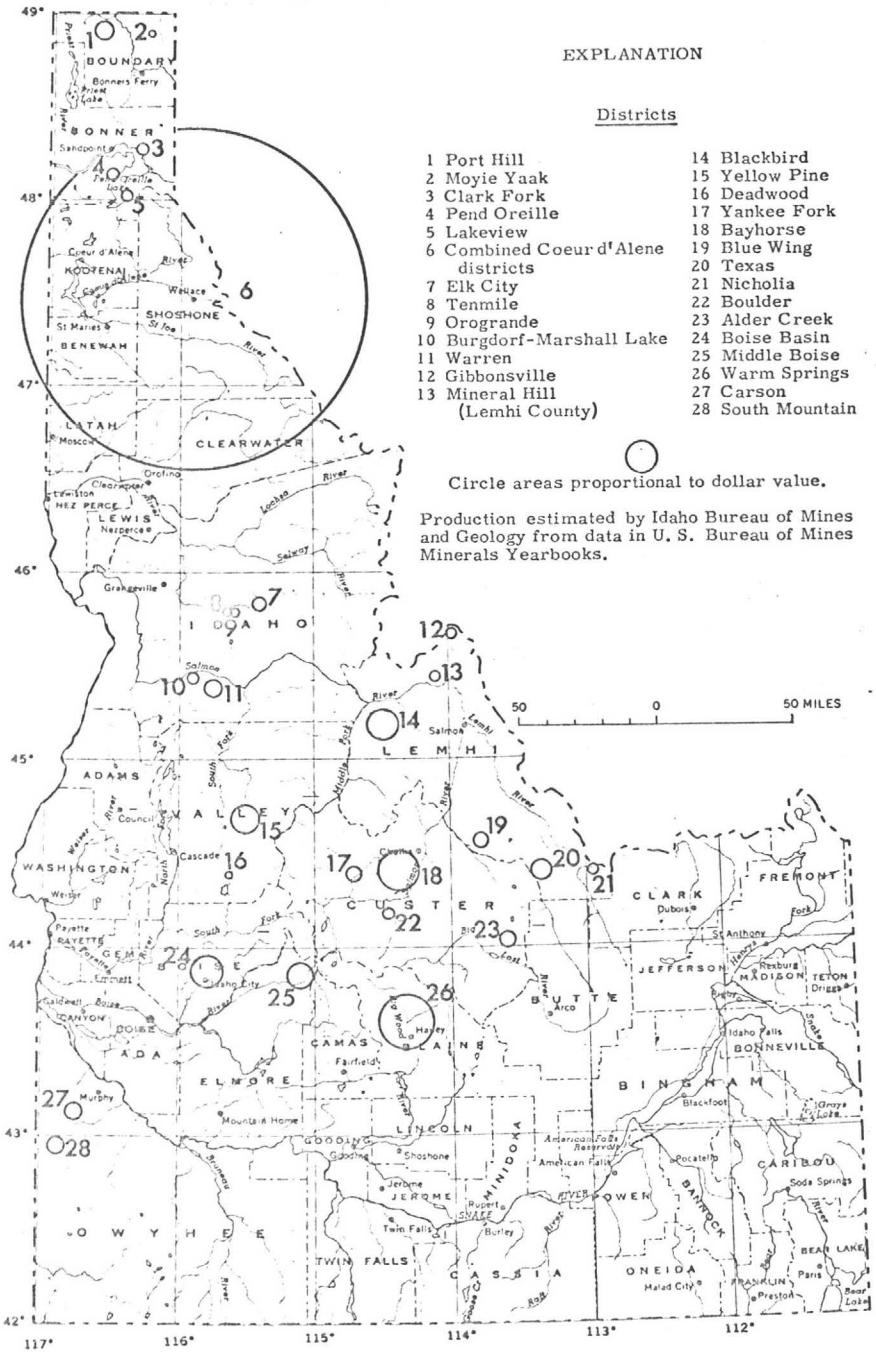

FIGURE 3.—Gold, silver, lead, zinc, and copper production in Idaho by Mining districts.

the production of gold, silver, lead, zinc, and copper since 1905. If production before that date had been considered—impracticable because of the lack of reliable records—some of the older districts would show more favorably. Cobalt, mercury, antimony, and tungsten have also contributed significantly to Idaho's mineral production, but production figures by districts are not available for these metals. If this production could have been included, such districts as Blackbird, Blue Wing, and Yellow Pine would have looked more impressive. In any case, the ratio between the Coeur d'Alene district and the rest of the State would not have been changed appreciably.

According to figure 2, the nonmetallic minerals have accounted for barely 10 percent of Idaho's total mineral production. This, however, underrates the present importance of the State's nonmetallic minerals. Previous to about 1920, the value of Idaho's nonmetallic mineral production was almost inconsequential. The growth of the nonmetallics industry began about 1938 and has been spectacularly rapid since about 1953. In 1923, the value of nonmetallic minerals amounted to a little over $1 million, or only 2.2 percent of the value of all mineral production. In 1938, only 15 years later, this had risen to 7.7 percent of the value of all mineral production, and the value was more than five times what it had been in 1923. In another 15 years, nonmetallic production had doubled and amounted to 17.7 percent of all minerals produced. In 1962, this figure had increased again to nearly 2½ times what it had been in 1953 and amounted to 36.7 percent of the value of all minerals produced. Figure 1 shows this increase graphically. Construction materials (sand and gravel and stone) and phosphate rock dominate the nonmetallic minerals industry (fig 2). The rapid expansion in the use of these commodities can be attributed to the increased utilization of fertilizers on western farms and to the greatly increased amount of highway and other construction within the State.

In 1962, the value of all minerals produced in Idaho amounted to $82.6 million, compared to cash receipts of $450.2 million from farm marketings (Fulkerson and others, 1963). Although overshadowed by agriculture, the mineral industry is nevertheless of great importance to Idaho's economy. In 1962, 3,266 men, with an annual payroll of $18.8 million, were employed in the State's mines and quarries; an additional 2,910 with an annual payroll of $17.7 million, were employed in smelters and plants directly concerned with processing mineral raw materials. Considering the relatively small population, the mineral industry obviously is a very important element in Idaho's economy.

The number of mines operating in Idaho and employment in the State's mineral industries are shown graphically in figure 4. The most striking feature of figure 4 is the tremendous increase in the number of placer mines during the 1930's and the sharp decline following that period. The sharp peak is partly the effect of the rise in the price of gold that occurred in the early 1930's, which made placer mining attractive. It also reflects the effect of the depression of the 1930's when many men, unable to find employment, attempted to eke out a living by operating small placer mines. The sharp decline is the effect of Order L-208, which prevented gold mines from obtaining needed supplies during World War II. Following the war, there was a brief revival of placer mining, but in the face of rising costs and a fixed

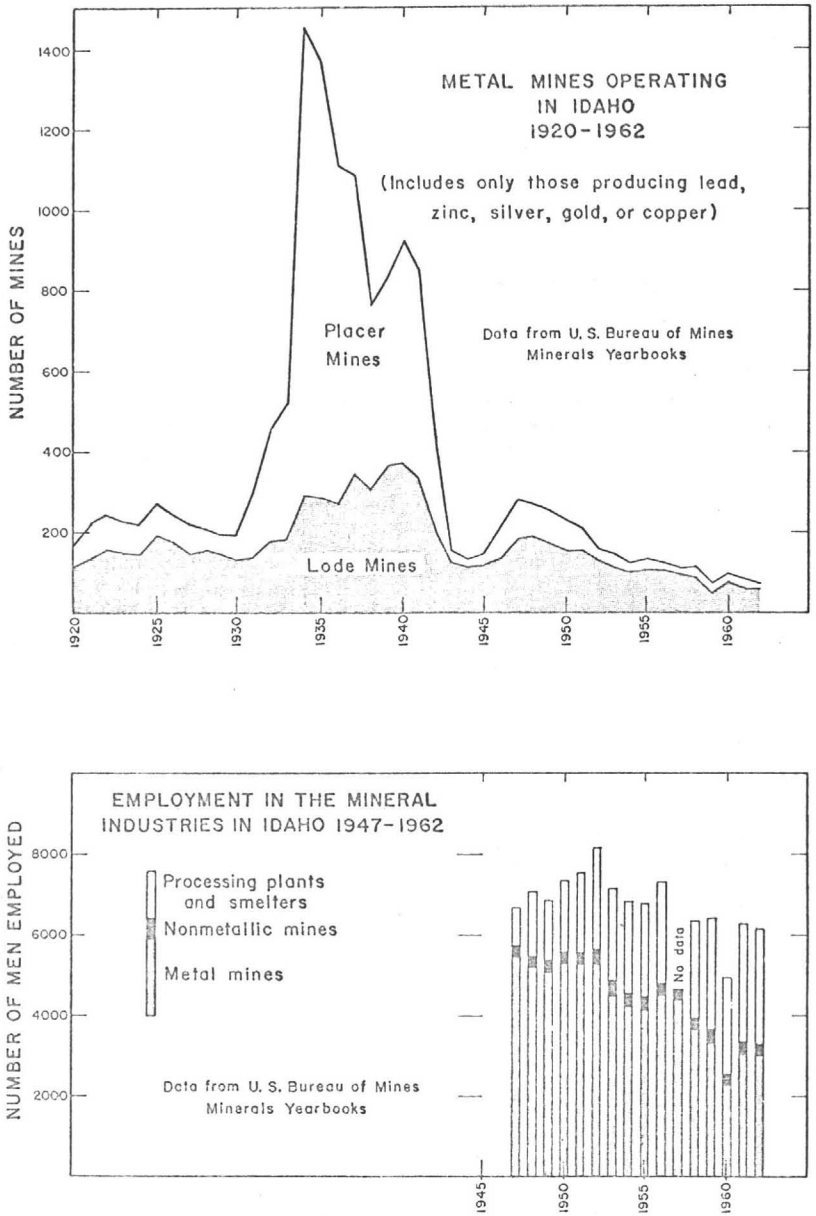

FIGURE 4.—Metal mines operating in Idaho 1920–62 and employment in the mineral industries in Idaho 1947–62.

price for gold nearly all the placer mines have closed. The production of placer gold is now insignificant.

Lode mining shows a somewhat different picture (fig. 4). From 1920 to 1940, the number of lode mines increased gradually. This was followed by a decline during World War II, as many small mines, especially gold mines, shut down because of manpower shortage or the inability to obtain needed supplies. Following the war, the number of mines in operation increased to another peak in 1947, but has been steadily declining ever since. This decline correlates closely with the sharp decline in the production curve for metals shown in figure 1 and brings out the effect of the slump in metal prices after the Korean conflict and the termination of the stockpiling program. The lower chart of figure 4 shows employment in Idaho's metal mines. Like metal production, it has undergone a significant decrease. In 1947, 5,439 were employed in Idaho's metal mines; in 1962, the labor force had decreased to 2,996. The low point was reached in 1960, when only 2,282 were employed in metal mines, but this figure is affected by a prolonged strike in the Coeur d'Alene district. With the current increased demand and more favorable prices for lead, zinc, and silver, it appears that a downward trend of employment may be halted and perhaps reversed.

The decrease in the labor force in metal mines has been partly offset by a significant increase in employment in processing plants (fig. 4). This is largely a result of an increase in employment in plants having to do with the preparation of phosphate fertilizers and in those that make stone, clay, and glass products (Fulkerson and others, 1963, p. 342). In spite of the great increase in the production of nonmetallic minerals, there has been no corresponding increase in employment at nonmetallic mines since 1947, probably because of increased mechanization of the mines.

The Coeur d'Alene district, Idaho, is one of the great mining districts of the world. It has produced more silver than any other district in the United States; it is one of the country's leading producers of both lead and zinc; and it is one of the very few districts in the world whose production is in excess of $2 billion. It far outshadows all other districts in Idaho, and all other districts in the Pacific Northwest, except Butte, Mont. It has been in continuous production for over 80 years; its metals have contributed significantly to the industrial might of our Nation in time of peace and have helped assure its security in time of danger. Its importance to the economy of Idaho and of the Pacific Northwest can scarcely be exaggerated.

The very importance of this single district to the mineral industry of the State is in itself a cause for some concern. In the past few years, the district has faced many serious problems brought on by low metal prices and rising costs. Some ore bodies have been mined out. Most of the mines are deep and are becoming deeper. The district must meet severe competition from domestic and foreign mines. The search for ore to replace that which has been extracted is difficult and expensive. Not all of it has been successful, but discoveries in recent years at the Galena and Lucky Friday mines have been particularly encouraging. Vigorous, well-planned exploration now in progress at a number of places in the district offers promise of new discoveries and continued life for many years to come. With rising prices and

increased demand for all three of the major metals the district produces, the situation has improved greatly.

Although it may be far in the future, eventually even such a mighty giant as the Coeur d'Alene district must wither and die. There is no district now known in Idaho that can take its place. However, given the need and the proper incentive, it is reasonable to expect that by vigorous exploration, and the use of the tools of geology, geochemistry, and geophysics now available—and perhaps others yet to be developed—other ore deposits or districts will be brought into production that will enable Idaho to maintain a strong position as a metal producer.

Idaho's nonmetallic mineral industry has grown mightily since World War II. Further growth seems assured. Idaho's population has increased slowly but steadily. With increased population and increasing industrialization, there should be greater need for many of the nonmetallic mineral products which Idaho now provides. These same factors should make feasible the development of deposits of other nonmetallic minerals which are not now being utilized but which are found in Idaho—some in considerable abundance. New developments in mineral technology will promote the use of new materials or utilize familiar materials in new ways. As an example, a recent announcement by the Anaconda Co. of the development of a method for economically extracting alumina from high-alumina clays could foreshadow the eventual large-scale utilization of Idaho's large resources of this material.

GEOLOGY

(By C. P. Ross, U.S. Geological Survey (retired), Denver, Colo.; R. R. Reid, Idaho Bureau of Mines and Geology, Moscow, Idaho; and A. E. Weissenborn, U.S. Geological Survey, Spokane, Wash.)

INTRODUCTION

Idaho, with an area of about 84,000 square miles, includes parts of three distinct physiographic provinces. These are the Northern Rocky Mountain province, the Columbia Intermontane province, and two small segments of the Basin and Range province. Each province differs markedly in topography, climate, and natural resources. Their distinctive character is a direct reflection of difference in the stratigraphy, structure, and chemical and physical composition of the underlying rocks, all of which profoundly affect human activity. Figure 5, slightly modified from a map previously published (Ross and Forrester, 1958, fig. 1), shows these provinces, as well as some of their subdivisions.

The State consists of a complex array of mountain ranges, intermontane valleys, and plains. The descriptions below are grouped mainly in accord with the three geomorphic provinces cited above, and are abstracted in large part from three recent summary papers (Ross and Forrester, 1958; Ross, 1962a, b).

TOPOGRAPHY

Idaho is one of the most scenic of the Western States. It is largely mountainous. The only major expanses of relatively gentle topography are the Snake River Plain and valleys along its southern border. Even these areas are dotted by hills, isolated and in groups, and gashed by steep-walled canyons.

The Northern Rocky Mountain province within northern and central Idaho consists of a rather ill-defined unsystematic assemblage of mountains that border the Snake River on the east and continue south to the Snake River Plain. The principal components which merge one into another are: Selkirk, Bitterroot, Clearwater, Salmon River, and Sawtooth Mountains (fig. 5). Some of the most scenic alpine topography in the United States can be found in the Sawtooth Mountains in the vicinity of Ketchum and Stanley.

Mountain ranges north of the Snake River Plain include the Beaverhead, Lemhi, and Lost River Ranges, and the Pioneer Mountains. Southeast of the Snake River Plain are such ranges as the Bannock, Port Neuf, and Bear River. Broad, elongate basins lie between these ranges, as is common in the main Basin and Range province to the south, of which this southern area is a part.

Altitudes above sea level range from 710 feet at the juncture of the Snake and Clearwater Rivers at Lewiston to 12,655 feet at Mount Borah in the Lost River Range, the highest point in the State. Mountain peaks in the narrow northern "Panhandle" of Idaho are mostly at altitudes of 7,000 feet or less. The Snake River Plain near the

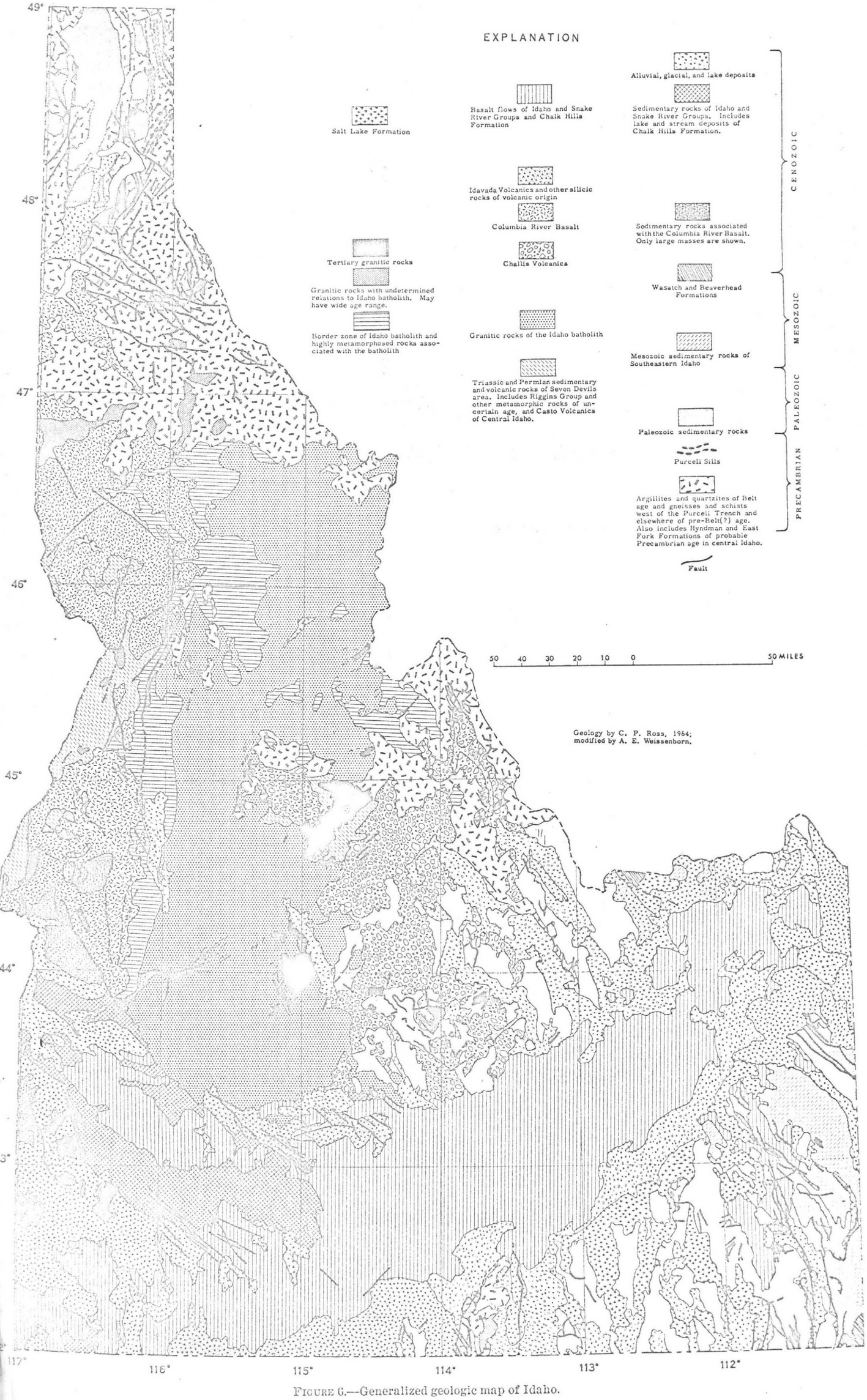

FIGURE 6.—Generalized geologic map of Idaho.

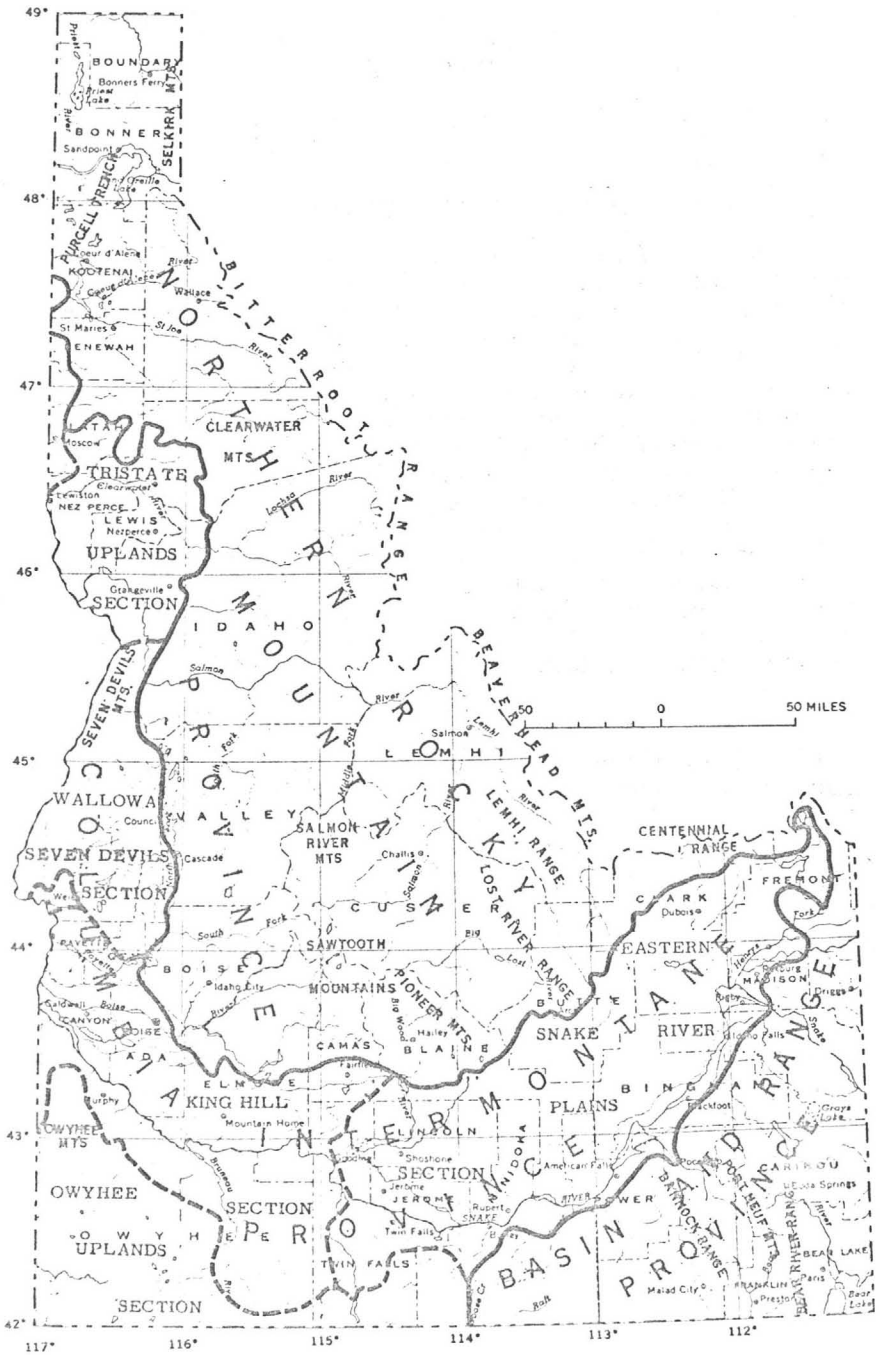

FIGURE 5.—Physiographic provinces and subdivisions in Idaho.

Oregon border is little more than 2,000 feet above the sea, but in its northeastern part its altitude exceeds 5,000 feet. Except for a few areas along its southeastern border, Idaho is in the drainage basin of the Columbia River, and most of it is drained by the Snake, Salmon, and Clearwater Rivers. In Hells Canyon below Homestead, the Snake River runs through a gorge 7,000 to 8,000 feet deep, the deepest on the North American Continent.

STRATIGRAPHY

Layered rocks of many geologic ages are exposed in Idaho and they record sequential changes in the geologic history of the State. The distribution and character of these rocks are reflected in the topography of the State. Along with the igneous and metamorphic rocks, they exert strong controlling effects on the nature and locations of the State's mineral resources. Distribution of the rock units—sedimentary, igneous, and metamorphic—which underlie the State is shown in figure 6, a greatly generalized geologic map of Idaho. This map is based on a previously published geologic map of Idaho by Ross and Forrester (1947) but embodies numerous changes based on later work, in part unpublished. On the map the different kinds of rocks are broadly differentiated by type and by geologic age. It is customary to give individual rock units specific names, and the stratigraphic nomenclature commonly used in various parts of Idaho is given in figure 7. Reference to this chart will be helpful in reading this section.

Precambrian Rocks

The oldest rocks in Idaho are Precambrian in age. Most of these belong to the Belt Series, but highly metamorphosed sedimentary rocks of uncertain but possibly older age occur at a few places in Idaho. Some gneisses in the Clearwater region underlie rocks of the Belt Series and may thus be pre-Belt (Anderson, 1930). Comparable rocks are found near Coeur d'Alene (Calkins and MacDonald, 1909, p. 33–35). These and other highly metamorphosed rocks that crop out in Kootenai County east of Mount Spokane and in the vicinity of Sandpoint may also be of pre-Belt age.

Other highly metamorphosed gneisses in northern Fremont County are continuous with known pre-Belt rocks in southwestern Montana, and their age is not in doubt. Similar-appearing rocks occur in northern Lemhi County, near and north of Shoup.

Strongly recrystallized sedimentary rocks, including schist, quartzite, and marble occur in central Idaho; for example, in the Sawtooth Range (Reid, 1963) and the Pioneer Mountains. These rocks bear no marked similarity to any of the above rocks; further, they bear little resemblance to Belt rocks. Their age is much in doubt, and their age assignment is highly tentative. Somewhat comparable rocks are found also in the Albion Range.

Precambrian rocks correlated with the Belt Series probably once covered all of central and northern Idaho and are still abundantly exposed, especially north of the North Fork of the Clearwater River. The series constitutes a thick unit composed mainly of argillaceous and quartzitic rocks with subordinate amounts of calcareous rocks. In Boundary County, some conglomerate and volcanic strata are

Boundary County			
Quaternary	Alluvium		
	Glacial deposits		
Precambrian	Belt Series	Purcell Basalt[1]	Piegan Group
		Kitchener Qtzite of Daly 19[illegible]	
		Creston Qtzite[1] of Daly 1906	Ravalli Group
		Aldridge Formation[1] of Schofield 1915 and Prichard Formation	

Coeur d'Alene region			
Quaternary	Alluvium		
	Glacial and terrace deposits		
Precambrian	Belt Series	Striped Peak Fm	Missoula Group
		Wallace Fm	Piegan Group
		St. Regis Fm	Ravalli Group
		Revett Formation	
		Burke Fm	
		Prichard Formation	

Pend Oreille region and Purcell Trench			
Quaternary	Alluvium		
	Glacial deposits		
	Palouse Formation		
Tertiary	Columbia River Basalt	Latah Formation	
Cambri[illegible]	Lakeview Limestone		
	Rennie Shale		
	Gold Creek Quartzite		
Precambrian	Belt Series	Libby Formation[1]	Missoula Group
		Striped Peak Formation	
		Wallace Formation	Piegan Group
		St. Regis Fm	Ravalli Group
		Burke Formation	
		Prichard Formation	
		Unnamed metamorphic rocks west of Purcell Trench	

1/ Not recognized or extended into Idaho by U. S. Geological Survey.

2/ Age uncertain

Orofino area		
Quaternary	Alluvium	
Tertiary	Columbia River Basalt	
Precambrian	Belt Series	Biotite schist of the Wallace and St. Regis Formations
		Revett Formation
		Biotite schist of the Burke and Prichard Formations
		Orofino Series[2] of Anderson 1930

Riggins and Seven Devils regions			
Quaternary	Alluvium		
Tertiary	Columbia River Basalt	Latah Formation	
Triassic	Lucile Slate[2]		
	Martin Bridge Formation		
	Seven Devils Volcanics	Riggins Group[2]	Squaw Creek Schist
			Berg Creek Amphibolite
			Lightning Cr. Schist
Permian			Fiddle Creek Schist

FIGURE 7.—Stratigraphic names commonly used in various parts of Idaho. Compiled by R. R. Reid and A. E. Weissenborn from many published sources and some unpublished material.

Salmon area		
Quaternary	Alluvium	
	Glacial deposits	
Tertiary	Challis Volcanics	Kirtley Formation of Anderson 1956
		Geertson Formation of Anderson 1956
		Kenney Formation of Anderson 1956
		Latite-andesite member
Cretaceous	Beaverhead Formation[1]	
Precambrian	Belt Series	Swanger Quartzite
		Lemhi Quartzite
		Apple Creek Phyllite of Anderson 1961
	Unnamed metamorphic rocks possibly equivalent to Cherry Creek Group of southwestern Montana	

Sawtooth Range	
Quaternary	Alluvium
	Glacial deposits
Permian	Wood River Fm
Pennsylvanian	
Precambrian	Thompson Peak Fm[2] of Reid 1963

Bayhorse region			
Quaternary	Alluvium		
	Glacial deposits		
Tertiary	Challis Volcanics	Yankee Fork Rhyolite Member	
		Germer Tuffaceous Member	
		Andesitic member	
Permian	Casto Volcanics[2]		
Pennsylvanian	Wood River Formation	Copper Basin Fm and White Knob Ls	
Mississippian	Milligen Formation[2]		
Devonian	Grand View Dolomite		
	Jefferson Dolomite		
Silurian	Laketown Dolomite		
	Trail Creek Fm		
Ordovician	Saturday Mountain Formation		
	Kinnikinic Qtzite		
	Ramshorn Slate		
Cambrian	Bayhorse Dolomite[2]		
	Garden Creek Phyllite[2]		
Precambrian	Belt Series	Hoodoo Quartzite	
		Yellowjacket Formation	

1/ Not recognized or extended into Idaho by U. S. Geological Survey

2/ Age uncertain.

Hailey-Wood River region	
Quaternary	Alluvium
Tertiary	Challis Volcanics
Permian and Pennsylvanian	Wood River Fm
Mississippian and Devonian(?)	Milligen Fm
Silurian	Trail Creek Fm
Ordovician	Phi Kappa Fm
Precambrian	East Fork Fm[2]
	Hyndman Fm[2]

Lost River Range and Borah Peak Quadrangle	
Quaternary	Alluvium
	Glacial deposits
Permian	White Knob Ls
Pennsylvanian	
Mississippian	Milligen Fm
?	Three Forks Ls
Devonian	Grand View Dolomite
	Jefferson Dolomite
Silurian	Laketown Dolomite
Ordovician	Saturday Mountain Formation
	Kinnikinic Qtzite

FIGURE 7.—Stratigraphic names commonly used in various parts of Idaho (continued).

35-920 O—64——3

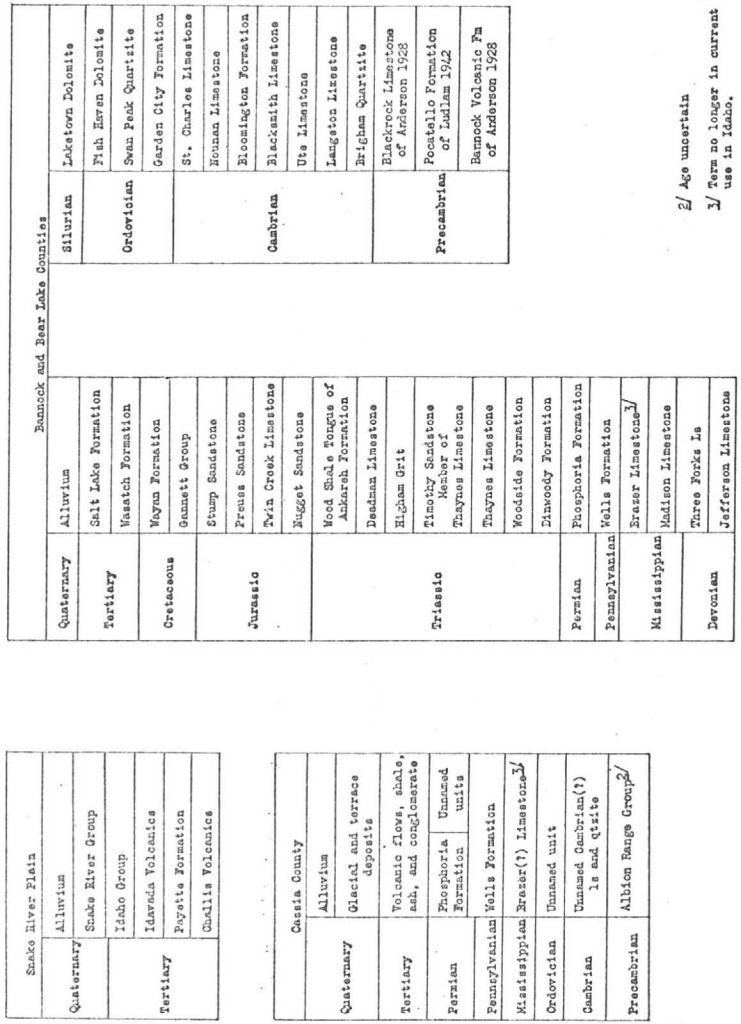

FIGURE 7.—Stratigraphic names commonly used in various parts of Idaho (continued).

included. Stromatolites (algal fossils), locally abundant in the Belt Series in Montana, are present also in Idaho. Probably the entire series was laid down in shallow marine water, but since deposition it has been subjected to widespread low-grade regional metamorphism. The aggregate thickness of Belt rocks in Idaho exceeds 20,000 feet in places, and in Montana the maximum thickness is thought to be over 40,000 feet.

The rocks of the Belt Series in most areas are recrystallized in varying degree but retain the appearance of sedimentary rocks. Locally, mostly near bodies of granitic rocks, they are so intensely metamorphosed that stratigraphic units are difficult or even impossible to recognize.

The stratigraphy of the Belt Series in the Coeur d'Alene region of northern Idaho was established by Calkins (Ransome and Calkins, 1908, p. 22–44) as the Prichard, Burke, Revett, St. Regis, Wallace, and Striped Peak formations. This succession is still accepted as the standard for that part of the State. These rocks are argillitic and quartzitic in the lower part of the section, and grade upward into limy argillites and quartzites. Many of the argillites might more properly be called slates.

In Boundary County, Kirkham and Ellis (1926) have used Canadian names to identify the rocks of the Belt Series. Their practice is not generally accepted, but their terminology is given in figure 7. These units cannot be correlated precisely with the Coeur d'Alene units. For long-range correlations, the broader terms pre-Ravalli, and Ravalli, Piegan, and Missoula groups are used (Ross, 1963b). In Boundary County and in Bonner County to the south, the Belt rocks are intruded by sheet-like bodies of gabbro and diorite commonly known as the Purcell sills. In the extreme northwestern part of Boundary County, Precambrian volcanic rocks rest on the Belt Series.

Most of the formations of the Belt Series in the Coeur d'Alene region are thought to have their counterparts in Clearwater County to the south (Hietanen, 1956; 1962; 1963 a, b, c) although intense metamorphism hampers recognition of stratigraphic units.

Still farther south, rocks regarded as correlatives of the Belt Series are known, mainly near the Middle Fork of the Salmon River and in the Lemhi and Lost River Ranges. Most of these are included in the Yellowjacket formation and in the Hoodoo, Lemhi, and Swauger quartzites. Thick quartzites crop out in the region about Salmon (Anderson, A. L., 1957; 1961) but they cannot be correlated with formations in northern Idaho. Probably only part of the stratigraphic range known farther north is represented by these formations. There is a stratigraphic break in central Idaho between the Belt Series and the overlying Paleozoic beds, but the angular discordance is slight.

Precambrian rocks in Bannock County are far from exposures of rocks regarded positively as belonging to the Belt Series and they differ from rocks in that series. They include volcanic rocks and probably tillite (ancient cemented debris deposited by a glacier). They resemble the Belt Series in that they underlie Cambrian strata and are separated from these younger rocks by a nearly concordant contact and, in a broad way, may be correlated generally with the Belt Series.

Only a few age determinations of Belt rocks from Idaho have been published. On the basis of radioactivity measurements of pitchblende from the Sunshine mine, Coeur d'Alene district, Eckelmann and Kulp (1957, p. 1129–1130) concluded that the uranium mineralization occurred about 1,190 million years ago. The rocks that enclose the uranium minerals must therefore be still older (Wallace and others, 1960, p. 25).

PALEOZOIC ROCKS

Stratified rocks of Paleozoic age are abundant in southeastern Idaho and in parts of central Idaho east of the southern part of the Idaho batholith. The aggregate preserved thickness of Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian stratified marine rocks is well in excess of 50,000 feet; however, it is unlikely that Paleozoic rocks of that thickness were deposited at any one place or over broad areas. Rather, deep basins in which these sediments were deposited probably existed at different places and times during the Paleozoic.

The only thick and diverse strata assigned a Cambrian age are in and near Bannock and Bear Lake Counties, where a thick succession of quartzite and limestone is found. Thinner sandstones, limestones, and shales are known to the north, along the Montana line. In Custer County, phyllite and dolomite of possible Cambrian age are known. Quartzite, shale, and limestone of Cambrian age at Lake Pend Oreille in Bonner County lie in a downfaulted block surrounded by Belt rocks.

Ordovician quartzites, shales, and limestones are best known in eastern and southeastern Idaho, but extend into central Idaho east of the Idaho batholith. Silurian and Devonian strata have much the same distribution.

Mississippian, Pennsylvanian, and Permian strata, including sandstones, shales, and limestones much like those of neighboring Wyoming, Montana, and Utah, are found in eastern and southeastern Idaho. Among these are the White Knob Limestone and Copper Basin Formation, two assemblages of limestone and conglomerate more than 10,000 feet thick that range in age from Mississippian to Permian. In eastern and southeastern Idaho, the Phosphoria Formation of Permian age contains important phosphate deposits. A thick unit of volcanic rocks of Permian age is exposed in central Idaho near the Middle Fork of the Salmon River. Comparable volcanic rocks are also found in the Seven Devils region of western Idaho. In their upper part, the Seven Devils Volcanics are of Permian and Triassic age.

MESOZOIC ROCKS

Marine sandstones, shales, and limestones of Triassic age are exposed in southeastern Idaho in Bear Lake County, the Sublett Range, and in small areas near the Montana boundary. In western Idaho, in addition to volcanic rocks in the Seven Devils Volcanics, sedimentary strata thought to be of Triassic age extend interruptedly from areas in Washington County to near Grangeville in Idaho County. Argillaceous rocks, in part schistose, predominate but limestone, sandstone, and conglomerate are also present.

Jurassic strata have a distribution in Idaho similar to that of the Triassic rocks just described. Most of the formations of Jurassic age are separated from each other by unconformities, whereas most of the Triassic units are mutually conformable. Hamilton (1963a) describes a unit along the Salmon River near Riggins consisting of slate, with some intercalated limestone, that probably is only a few hundred feet thick. Possibly Jurassic strata exist elsewhere in western Idaho.

A thick series of fresh-water and marine sedimentary rocks of Cretaceous age, largely sandstones and shales, cover large sections of southeast Idaho. One of these stratigraphic units, the Frontier Formation of Upper Cretaceous age, contains the most productive coal beds in the State.

CENOZOIC ROCKS

Cenozoic strata of Idaho are partly nonmarine sedimentary rocks and partly volcanic rocks ranging in composition from basalt to rhyolite.

Of the sedimentary rocks, the most widespread are those of the Idaho and Snake River Groups, which are found abundantly on the Snake River Plain. The Idaho Group of Pliocene and Pleistocene ages (Malde and Powers, 1962; Malde and others, 1963) includes seven formations which contain sediments, ash, and some basalt. The Snake River Group (Pleistocene and Recent) as now recognized, consists mainly of the younger part of the old Snake River Basalt, but includes some sedimentary rock. Sediments of the Idaho and Snake River Groups contain important deposits of diatomite and silica sands.

South of the Snake River Plain, beds of conglomerate and limestone with a maximum thickness of 1,500 feet been correlated with the Paleocene and Eocene Wasatch Formation of Utah. Beds of predominantly reddish conglomerate on the southern flank of the Centennial Mountains have been correlated with the Beaverhead Formation in Montana also of Cretaceous, Paleocene and Eocene age (Lowell and Klepper, 1953). Loosely consolidated clastic volcanic rocks of Pliocene age which mostly occupy intermontane valleys south of the Snake River Plain are grouped together on figure 6 as the Salt Lake Formation.

Poorly consolidated sand, silt, and gravel of lacustrine and fluvial origin are widespread in intermontane valleys in the southeastern part of the State. There are also wide areas of unconsolidated alluvium, glacial deposits, lake sediments, and windblown deposits of late Pleistocene to Recent age. These are all grouped together on figure 6 as "alluvial, glacial, and lake deposits."

Four major units of volcanic rocks are recognized in the State. These are the Challis Volcanics, the Columbia River Basalt, the Idavada Volcanics, and basalts of the Snake River Group.

The Challis Volcanics of Tertiary age are widespread in central Idaho. They consist dominantly of andesitic flows and interbedded pyroclastic rocks.[1] Conglomerate is common near the base. Locally a lower tuffaceous member fills depressions in the uneven surface upon which the Challis Volcanics were laid. The maximum thickness of the Challis Volcanics is about 5,000 feet.

[1] Pyroclastic rocks—a general term for indurated deposits of volcanic ejecta, including volcanic agglomerate, breccias, tuff-breccias, and tuffs.

A large part of western Idaho from the Owyhee Mountains north nearly to Coeur d'Alene Lake is covered by flows of the Columbia River Basalt of Miocene and Pliocene(?) age. These flows consist of basalt and calcic andesite with some agglomerate and tuff. In places they are as much as 3,000 feet thick. Intercalated with them and in places underlying them are fresh water sedimentary rocks which form the Latah and Payette Formations. The Columbia River Basalt is an important source of construction stone, pumice, and pumicite. Deposits of various types of clay, including high-alumina clay, are found in the Latah and Payette Formations, as are deposits of silica sand. Diatomite is mined from some beds in the Payette Formation.

The Idavada Volcanics and other silicic rocks are widely distributed along and near the border of the Snake River Plain. As shown on figure 6, they include rhyolitic rocks of early Pliocene age that intertongue with the Columbia River Basalt (Malde and Powers, 1962, p. 1200), early Pliocene ash flows, and—near the northern and northwestern border of the Snake River Plain—siliceous volcanic rocks which contain some interbedded sediments of Pliocene age.

Basalt of the Snake River Group covers large sections of the Snake River Plain, particularly the eastern two-thirds, and occupies the floors of some of the valleys to the south. Most of the flows are of Recent age and can be distinguished from the older basalts by their fresh appearance. They are exposed in spectacular fashion at the Craters of the Moon National Monument and at many other places on the Snake River Plain.

INTRUSIVE ROCKS

EARLY INTRUSIVE ROCKS

Sills and other intrusive bodies, mostly gabbro and diorite, intrude the Belt Series in northern Idaho but they are not quantitatively important. They are thought to have been emplaced near the end of the Precambrian Era.

Syenitic rocks in Idaho County north of Big Creek are provisionally regarded (Leonard, 1963) as of Paleozoic age, but may be older.

INTRUSIVE ROCKS OF MESOZOIC AGE

The Idaho batholith

The Idaho batholith, a striking geologic feature of the State, is one of the world's largest bodies of granitic rock. It is exposed from southern Elmore County northward through central Idaho and into Montana—an area nearly 250 miles long and 80 to 100 miles wide. It consists of a main body of granitic rocks and a complex and varied but incomplete border zone. Most of the intruded rocks in north-central Idaho belong to the Belt Series, but Paleozoic strata have been intruded on the southeast. On the west side, Triassic and possibly Jurassic rocks have been invaded. Lead-alpha analyses indicate an average age of the batholithic rocks somewhat in excess of 100 million years, which accords fairly well with the hypothesis of Late Cretaceous age arrived at by geologic means. Much of the batholith is overlapped unconformably by Tertiary volcanic rocks, some of which may be as old as Eocene.

The main mass of the batholith is granodiorite and quartz monzonite, but other rock types are included. Much of the batholith appears to have been intruded as a unit or as a number of large, related, and possibly gradational units.

Within the border zone of the Idaho batholith, the sedimentary rocks have been metamorphosed to gneisses and schists, within which are bodies of igneous rocks including quartz diorite, tonalite, and other rocks thought to be of metasomatic origin but with textures that resemble those of rocks of magmatic origin (Hamilton, 1963a; Hietanen, 1956, 1962). Aplite and pegmatite are abundant in some of the gneisses.

Outlying intrusives

Smaller batholiths and stocks are exposed on all sides of the Idaho batholith and at varying distances from it. These include the Kaniksu batholith (which extends from south of Pend Oreille Lake northward into British Columbia), the Owyhee batholith in Owyhee County, granitic masses in Cassia County, and numerous other small plutons (fig. 6). These have sufficient resemblance to the Idaho batholith so that in the past they have been assumed to be related to it, but many of them cannot be closely dated on the basis of field relations. Two age determinations from the Gem stock near Wallace indicate that this body is about the same age as the Idaho batholith (Jaffe and others, 1959, p. 159–160), but Lowdon (1961, p. 102) has shown that parts of the extension of the Kaniksu batholith into British Columbia may be of Tertiary age. An increasing number of outlying intrusive bodies in Idaho are likewise suspected of being Tertiary in age, and thus not directly related to the Idaho batholith. Granitic rocks that cut the Seven Devils Volcanics in western Idaho, however, are somewhat metamorphosed and may be older than the batholith.

TERTIARY INTRUSIVE ROCKS

Granitic rocks of Tertiary age crop out at several places in central Idaho. They are extensively developed along the Middle Fork of the Salmon River and in the Sawtooth Mountains (Reid, 1963). These, with associated dikes, form a wide northeast-trending belt that extends from Boise County into Idaho County. Small stocks of Tertiary age are scattered through Custer, Blaine, and Butte Counties east of the Idaho batholith, and Tertiary dikes are plentiful throughout central Idaho. The granitic rocks generally range in composition from granite to diorite. They are regarded as 60 million years old or younger and are believed to be related to the Challis Volcanics, but some may be older (Anderson, 1952). Small masses of potassium-rich rocks in Bonneville County are regarded by Anderson and Kirkham (1931) as of Tertiary age.

GEOLOGIC HISTORY

The geologic history of Idaho is complex. The area now occupied by the Idaho batholith, as well as most of the area to the north, is

thought to have been a landmass or a "structurally positive" block since the end of the Precambrian. It stood above the Paleozoic seas while sediments were being deposited in basins to the east and southeast (Ross, 1962b). Sediments were also being deposited on the west, but to a lesser extent. Although there was no major crustal deformation during the Paleozoic Era, these basins of deposition were raised above sea level many times, resulting in numerous breaks in the stratigraphic record.

The Mesozoic Era was marked by powerful crustal deformation and by large-scale igneous activity. The structurally positive area of central Idaho was sharply uplifted early in the era and the structurally weak Paleozoic sediments were flexed into long folds. The main part of the Idaho batholith was emplaced during the Cretaceous Period. The sedimentary rocks were refolded and, along the southeastern border, were intricately contorted in broad conformity with the shape of the batholithic mass. On the east side of the batholith the sediments have been thrust to the northeast along low-dipping thrust faults. Similar faults along which the rocks have been thrust to the northwest have recently been recognized by Hamilton (1960), and, like those to the east, may be related to the emplacement of the batholith. Genetic relations between emplacement of the batholith and deformation of the stratified rocks seem clear, but whether the intrusion of the granitic rocks was the cause of the deformation or whether the deformation created an area of "low pressure" into which the granite rocks made their way is open to argument. Certainly in some localities the evidence seems compelling that the granitic rocks were injected forcibly.

Further folding and the development of faults, many with northeast trend, acompanied and followed the eruption of the Challis Volcanics and the intrusion of related igneous rocks in the early part of the Tertiary. Faulting and mild warping continued during Miocene time and affected the Columbia River Basalt (Hamilton, 1963b).

Two main periods of deformation, a gentle warping in the Jurassic and a more intense one in the Cretaceous, mark the two major periods of folding in central and southeastern Idaho. The folds trend northwest and are broken by numerous faults, mostly reverse faults. In early studies a long and folded thrust fault called the Bannock overthrust was postulated (Mansfield, 1927, p. 150–152), but this has recently been reinterpreted as an imbricate thrust zone composed of several separate faults (Armstrong and Cressman, 1963).

In the northern part of Idaho, the rocks of the Belt Series almost everywhere have been folded into a series of broad folds that commonly trend west of north, but they have been intensely deformed in the vicinity of some of the major faults. The outstanding structural feature is a complex system of northwesterly trending faults that occupy a zone extending from the St. Joe River northward to the north end of Pend Oreille Lake (fig. 6). This is but a small segment of a major structural break known as the "Lewis and Clark line" that extends from Idaho for many miles eastward into Montana (Wallace and others, 1960, p. 25; Billingsly and Locke, 1939, p. 36). Displacement is large along the major faults that make up the Lewis and Clark line. One segment of the "line" is represented by the Osburn Fault, which passes through

the Coeur d'Alene district. The rocks on the north side of this fault are believed to have moved about 12 miles eastward relative to the south side (Wallace and others, 1960), dividing the district into two distinct parts. Eastward displacement of the north side of the Hope Fault, the northernmost member of the "line," has been estimated to be as much as 8 miles (Harrison and Jobin, 1963). It is probable that these and other faults of the system are old structural breaks along which movement has occurred at several different times.

The most striking young structural feature in the State is the Snake River Plain—a great, curving depression now filled mostly by volcanic rocks. This depression was formerly thought of as almost entirely the result of a downwarp (Kirkham, 1927, p. 24–26; Kirkham, 1931), but recent mapping by Malde and others (1963) has demonstrated the presence of many normal faults in the western part of the plain, showing that the rocks have been fractured and not merely downwarped. These faults do not, however, eliminate downwarping as a contributory factor, especially in the eastern part of the plain.

ECONOMIC GEOLOGY

Each of the major periods of deformation outlined above has had deposits of metallic minerals related to it, but assignment of specific deposits to the appropriate periods presents difficulties. Some metallic mineralization probably took place in Precambrian time (Anderson, 1951, pp. 593–594) but deposits regarded as Precambrian have not proved to be of much economic significance. Numerous determinations of the age of the lead in the deposits of the Coeur d'Alene district, the most important in the State, give results indicating a Precambrian age (Cannon and others, 1962; Kerr and Kulp, 1952; Kerr and Robinson, 1953). However, most geologists familiar with the Coeur d'Alene district believe that the economically important ore deposits were emplaced late in Cretaceous time.

It has long been customary to regard most of the metallic mineral deposits in Idaho, including nearly all the productive lead-silver deposits, as being related to the Idaho batholith. This deduction is supported by the spatial association of some deposits with the batholith or with subsidiary intrusions related to it, by abundant evidence that the deposits are of mesothermal type and formed at considerable depth, and by mineralogical similarities that indicate a similarity of source material (Ross, 1931, 1933). The possibility has been pointed out (Anderson, 1951), however, that many deposits commonly regarded as related to the Idaho batholith may date from an early Tertiary epoch of mineralization associated with intrusions later than the Idaho batholith.

Many gold-silver deposits are found in the Challis Volcanics and other volcanic rocks of Tertiary age, and other gold-silver deposits are clearly associated with Tertiary intrusives. They obviously must have been emplaced after the intrusion of the Idaho batholith. Some precious metal deposits, including some that have produced richly in the past, may be associated with a still younger period of Tertiary

mineralization. Mercury deposits in the State are also believed to be of middle to late Tertiary age or later.

Deposits of nonmetallic minerals are many and varied. They include fluorspar and barite in veins and replacement; clays derived from the weathering of granitic rocks; bedded deposits such as diatomite, volcanic ash, and silica sand found in the volcanic and interbedded sedimentary rocks on the Snake River Plain; phosphate deposits found in phosphorite beds of Permian age in southeastern Idaho; as well as numerous minerals such as garnet, monazite, and thorium minerals derived from the weathering of metamorphic or igneous rocks. The occurrences, economic importance, and geologic association of these and many other commodities are described in the various commodity chapters of this report.

Water resources in the State are strongly influenced by the topography and by the geology and structure of the underlying rocks. The heaviest precipitation, much of which falls as snow at higher elevation, is in the mountainous parts of the State; the least is on the Snake River Plain. Numerous aquifers are sources of ground water in many parts of the State. The sequence of lava flows beneath the Snake River Plain is one of the world's most productive aquifers. Spectacular amounts of water are discharged through these flows into the Snake River at Thousand Springs and at other large springs in the Snake River Canyon. Surface- and ground-water resources of the State are discussed in considerable detail in the section on water resources.

A mineral deposit, whether it is metalliferous or nonmetallic, is merely an unusual concentration of some mineral or minerals that are present in many rocks. It is the result of a combination of geologic processes that have caused this concentration at some particular place. As such, it is an integral part of the stratigraphy, structure, and geologic history of the area in which it occurs. The more thoroughly the geology is known, the more effectively the mineral potential of the area can be assessed and exploration of its mineral resources be done. Knowledge of the geology is also essential for the proper development of the water resources of a region, particularly the ground-water resources.

For accurate recording of geologic and other data and for a multitude of planning purposes topographic maps are a necessity. Figure 8 shows the areas of Idaho that have been mapped topographically on a scale of about 1 inch to the mile or larger and for which maps are available from the Geological Survey. Although topographic maps are available for the more populated areas, a large part of the State—including many of the important mineralized regions—has not been adequately mapped. Figure 9 is a similar map showing the status of geologic mapping in the State through the efforts of various agencies. Only about half the State has been mapped geologically on scales larger than 1:250,000; of this, only a small portion has been mapped geologically on a scale of 1 inch to the mile or larger. The remainder has been mapped only in reconnaissance or not at all. Obviously much topographic and geologic mapping remains to be done before the State of Idaho can be considered to have adequate coverage.

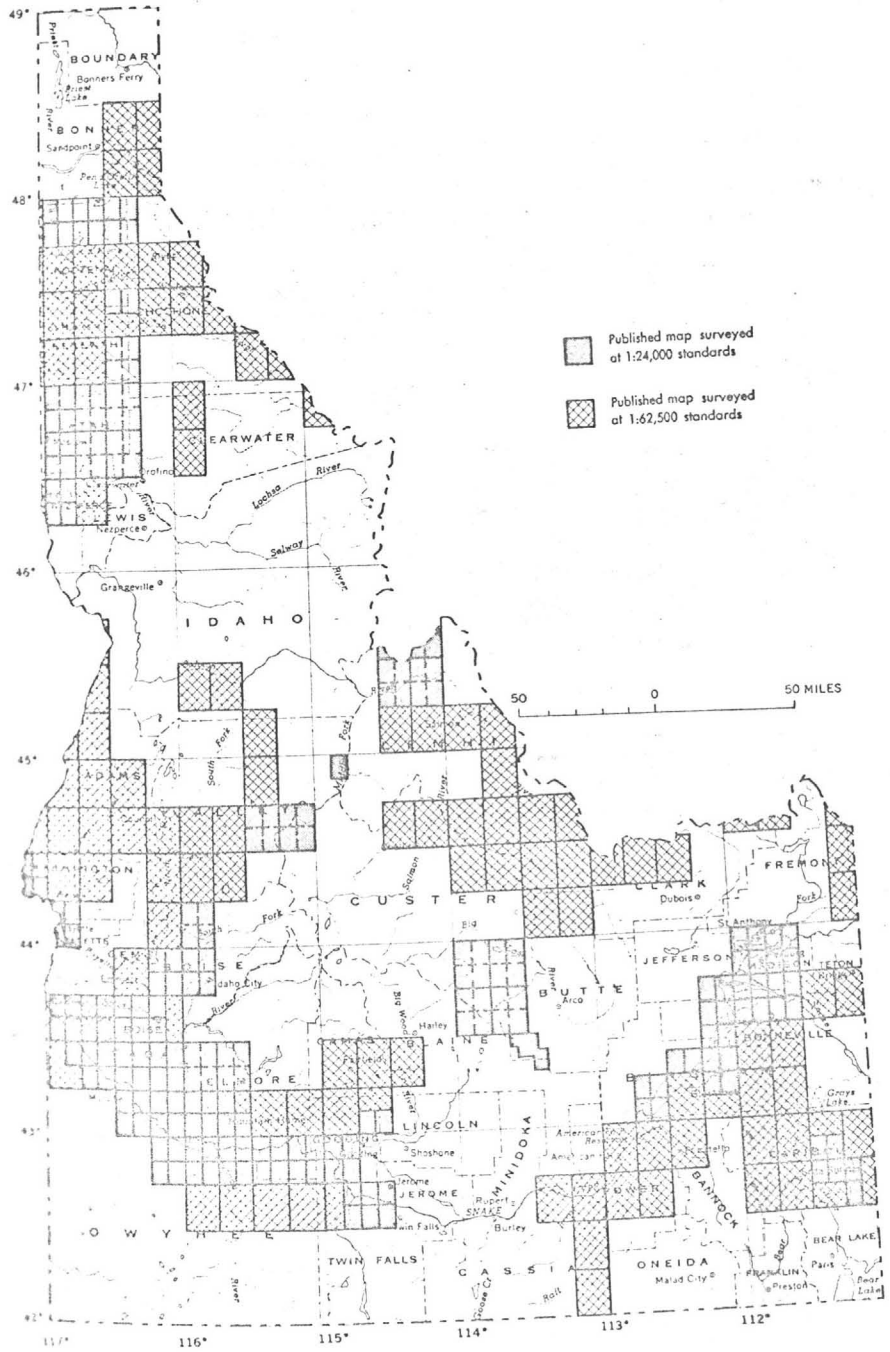

FIGURE 8.—Published topographic mapping in Idaho, November 1963.

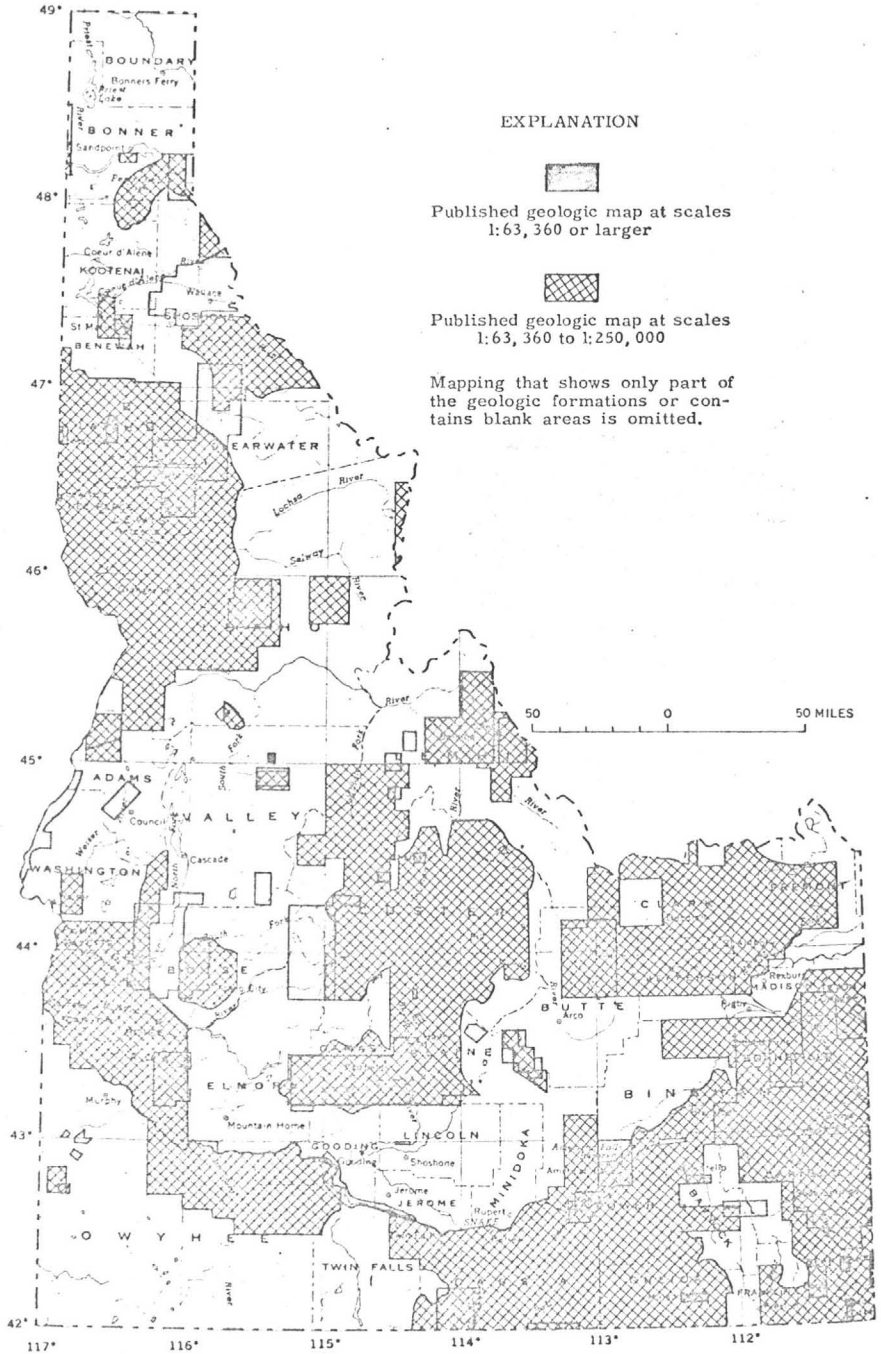

FIGURE 9.—Published geologic mapping in Idaho, January 1964.

SELECTED REFERENCES

Anderson, A. L., 1930, The geology and mineral resources of the region about Orofino, Idaho: Idaho Bur. Mines and Geology Pamph. 34, 63 p.

——— 1951. Metallogenic epochs in Idaho: Econ. Geology, v. 46, no. 6, p. 592–607.

——— 1952, Multiple emplacement of the Idaho batholith: Jour. Geology, v. 60, no. 3, p. 255–265.

——— 1957, Geology and mineral resources of the Baker quadrangle, Lemhi County, Idaho: Idaho Bur. Mines and Geology Pamph. 112, 70 p.

——— 1961, Geology and mineral resources of the Lemhi quadrangle, Lemhi County: Idaho Bur. Mines and Geology Pamph. 124, 111 p.

Anderson, A. L., and Kirkham, V. R. D., 1931, Alkaline rocks of the Highwood type in southeastern Idaho: Am. Jour. Sci., 5th ser., v. 22, p. 51–68.

Armstrong, F. C., and Cressman, E. R., 1963, The Bannock thrust zone, southeastern Idaho: U.S. Geol. Survey Prof. Paper 374–J, 22 p.

Billingsley, P. R., and Locke, Augustus, 1939, Structure of ore districts in the continental framework: New York, Am. Inst. Mining Metall. Engineers, 51 p.

Bolino, A. C., 1960, The role of mining in the economic development of Idaho Territory: Idaho Bur. Mines and Geology Inf. Circ. 6, 38 p.

Calkins, F. C., and MacDonald, D. F., 1909, A geological reconnaissance in northern Idaho and northwestern Montana, with notes on the economic geology: U.S. Geol. Survey Bull. 384, 112 p.

Cannon, R. S., Jr., Pierce, A. P., Antweiler, J. C., and Buck, K. L., 1962, Lead-isotope studies in the Northern Rockies, U.S.A., *in* Petrologic studies (Buddington volume): Geol. Soc. America, p. 115–131.

Eckelmann, W. R., and Kulp, J. L., 1957, Uranium-lead method of age determination (Part 2: North American localities): Geol. Soc. America Bull., v. 68, no. 9, p. 1117–1140.

Fulkerson, F. B., Knostman, R. W., and Petersen, N. S., 1963, The mineral industry of Idaho: U.S. Bur. Mines Minerals Yearbook 1962, v. 3, p. 339–361.

Hamilton, Warren, 1960, Metamorphism and thrust faulting in the Riggins quadrangle, Idaho: U.S. Geol. Survey Prof. Paper 400–B, p. 230–233.

——— 1963a, Metamorphism in the Riggins Region, western Idaho: U.S. Geol. Survey Prof. Paper 436, 95 p.

——— 1963b, Columbia River basalt in the Riggins quadrangle, western Idaho: U.S. Geol. Survey Bull. 1141–L, 37 p.

Harrison, J. E., and Jobin, D. A., 1963, Geology of the Clark Fork quadrangle, Idaho-Montana: U.S. Geol. Survey 1141–K, 38 p.

Hietanen, Anna, 1956, Kyanite, andalusite, and sillimanite in the schist in Boehls Butte quadrangle, Idaho: Am. Mineralogist, v. 41, nos. 1 and 2, p. 1–27.

——— 1962, Metasomatic metamorphism in western Clearwater County, Idaho: U.S. Geol. Survey Prof. Paper 344–A, 116 p.

——— 1963a, Anorthosite and associated rocks in the Boehls Butte quadrangle and vicinity, Idaho: U.S. Geol. Survey Prof. Paper 344–B, 78 p.

——— 1963b, Metamorphism of the Belt Series in the Elk River-Clarkia area, Idaho: U.S. Geol. Survey Prof. Paper 344–C, 49 p.

——— 1963c, Idaho batholith near Pierce and Bungalow, Clearwater County, Idaho: U.S. Geol. Survey Prof. Paper 344–D, 42 p.

Jaffe, H. W., Gottfried, David, Waring, C. L., and Worthing, H. W., 1959, Lead-alpha age determinations of accessory minerals of igneous rocks (1953–1957): U.S. Geol. Survey Bull. 1097–B, p. 65–148.

Kerr, P. F., and Kulp, J. L., 1952, Pre-Cambrian uraninite, Sunshine mine, Idaho: Sci., v. 115, p. 86–88.

Kerr, P. F., and Robinson, R. F., 1953, Uranium mineralization in the Sunshine mine, Idaho: Mining Eng., v. 5, no. 5, p. 495–511.

Kirkham, V. R. D., 1927, A geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho: Idaho Bureau of Mines & Geology Pamph. 19, 47 p.

Kirkham, V. R. D., 1931, Snake River downwarp: Jour. Geology, v. 39, no. 5, p. 456–482.

Kirkham, V. R. D., and Ellis, E. W., 1926, Geology and ore deposits of Boundary County, Idaho: Idaho Bur. Mines and Geology Bull. 10, 78 p.

Leonard, B. F., 1963, Syenite complex older than the Idaho batholith, Big Creek quadrangle, central Idaho: U.S. Geol. Survey Prof. Paper 450–E, p. 93–97.

Lowdon, J. A., 1961, Age determinations by the Geological Survey of Canada (Report 2—Isotopic ages): Canadian Geol. Survey Paper 61–17, 127 p.

Lowell, W. R., and Klepper, M. R., 1953, Beaverhead Formation, a Laramide deposit in Beaverhead County, Montana: Geol. Soc. America Bull., v. 64, no. 2, p. 235–243.
Malde, H. E., and Powers, H. A., 1962, Upper Cenozoic stratigraphy of western Snake River Plain, Idaho: Geol. Soc. America Bull., v. 73, no. 10, p. 1197–1219.
Malde, H. E., Powers, H. A., and Marshall, C. H., 1963, Reconnaissance geologic map of west-central Snake River Plain, Idaho: U.S. Geol. Survey Misc. Geol. Inv. Map I–373.
Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U.S. Geol. Survey Prof. Paper 152, p. 1–409.
Ransome, F .L., and Calkins, F. C., 1908, The geology and ore deposits of the Coeur d'Alene district, Idaho: U.S. Geol. Survey Prof. Paper 62, 203 p.
Reid, R. R., 1963, Reconnaissance geology of the Sawtooth Range: Idaho Bur. Mines and Geology Pamph. 129, 37 p.
Ricard, T. A., 1932, A history of American mining: New York, McGraw-Hill Book Co., Inc., Am. Inst. Mining Metall. Ser., 419 p.
Ross, C. P., 1930, A graphic history of metal mining in Idaho: U.S. Geol. Survey Bull. 821–A, p. 1–9.
Ross, C. P., 1931, A classification of the lode deposits of south-central Idaho: Econ. Geology, v. 26, no. 2, p. 169–185.
Ross, C. P., 1933, The ore deposits of Idaho in relation to structural and historical geology, *in* Ore deposits of the western States (Lindgren volume): New York, Am. Inst. Mining Metall. Engineers, p. 265–272.
Ross, C. P., 1962a, Upper Paleozoic rocks in central Idaho: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 3, p. 384–387.
Ross, C. P., 1962b, Stratified rocks in south-central Idaho: Idaho Bur. Mines and Geology Pamph. 125, 126 p.
Ross, C. P., 1963a, Mining history of south-central Idaho: Idaho Bur. Mines and Geology Pamph, 131, 29 p.
Ross, C. P., 1963b, The Belt Series in Montana: U.S. Geol. Survey Prof. Paper 346, 122 p.
Ross, C. P., and Forrester, J. D., 1947, Geologic map of the State of Idaho: U.S. Geol. Survey and Idaho Bur. Mines and Geology.
Ross, C. P., and Forrester, J. D., 1958, Outline of the geology of Idaho: Idaho Bur. Mines and Geology Bull. 15, 74 p.
Umpleby, J. B., Westgate, L. G., and Ross, C. P., 1930, Geology and ore deposits of the Wood River region, Idaho: U.S. Geol. Survey Bull. 814, 250 p.
Wallace, R. E., Griggs, A. B., Campbell, A. B., and Hobbs, S. W., 1960, Tectonic setting of the Coeur d'Alene district, Idaho: U.S. Geol. Survey Prof. Paper 400–B, p. 25–27.
Wells, M. W., undated (1961?), Rush to Idaho: Idaho Bur. Mines and Geology Bull. 19, 57 p.
Wells, M. W., undated (1964?), Gold camps and silver cities: Idaho Bur. Mines and Geology Bull. 22, 86 p.

MINERAL RESOURCES

ANTIMONY

(By B. A. La Heist, U.S. Geological Survey, Washington, D.C.)

Domestic mine production of antimony metal has come chiefly from Idaho, which has furnished the entire U.S. output during many of the past 10 years. The total antimony production in Idaho from the beginning to 1960 has an estimated value of $17,300,000. The United States is the largest consumer of antimony metal and its products in the world. Much of the antimony is imported; from China in the past and, since about 1935, from Mexico and Bolivia. (See table 1 for a comparison of Idaho and U.S. mine production of antimony.)

TABLE 1.—*Mine production of antimony in Idaho and the United States, 1932 to 1962, in short tons of contained metal*[1]

Year	Idaho	United States	Year	Idaho	United States
1932 [2]	414	419	1949	[3] 1,436	1,636
1933	587	587	1950	[3] 2,450	2,497
1934	404	404	1951	[3] 2,900	3,472
1935	[3] 40	559	1952	1,900	2,160
1936	729	755	1953	(4)	372
1937	754	1,266	1954	764	766
1938	[3] 390	650	1955	633	633
1939	209	393	1956	549	590
1940	[3] 302	494	1957	664	709
1941	655	1,214	1958	677	705
1942	2,715	2,944	1959	678	678
1943	5,231	5,556	1960	635	635
1944	[3] 1,680	4,735	1961	689	689
1945	1,872	1,930	1962	631	631
1946	2,455	2,505			
1947	5,157	5,316	Total	44,235	52,389
1948	6,035	6,489			

[1] Antimony sections in annual volumes: U.S. Bureau of Mines and Minerals Yearbooks, 1932–62; U.S. Bureau of Mines Mineral Resources, United States 1924–31; U.S. Geological Survey Mineral Resources, United States 1882–1923; Idaho Bureau of Mines and Geology Pamphlet 105, 1955, p. 4.
[2] Prior to 1932, antimony production in Idaho and the United States was intermittent and negligible on a yearly basis except possibly for the years 1915 to 1918, when the World War I demand for antimony spurred a production of several thousand tons for that period.
[3] Estimated.
[4] Not available.

Antimony is used in alloys and compounds with other metals and nonmetals. It imparts hardness and color, expands on solidifying, is fire resistant, and is resistant to corrosion by acids. Because of its diverse properties, it is used in the manufacture of ammunition, batteries (in the form of antimonial lead), type metal, bearing metal, cable coverings, collapsible tubes, foil and solder, and in the paint, fabric, ceramic, rubber, plastics, and electronics industries. Antimony compounds are also used in medicines (Callaway, 1960).

Commercial deposits of stibnite and tetrahedrite, the principal sources of antimony, are not abundant in the United States (White, 1951), but in Idaho antimony is recovered as a minor byproduct from

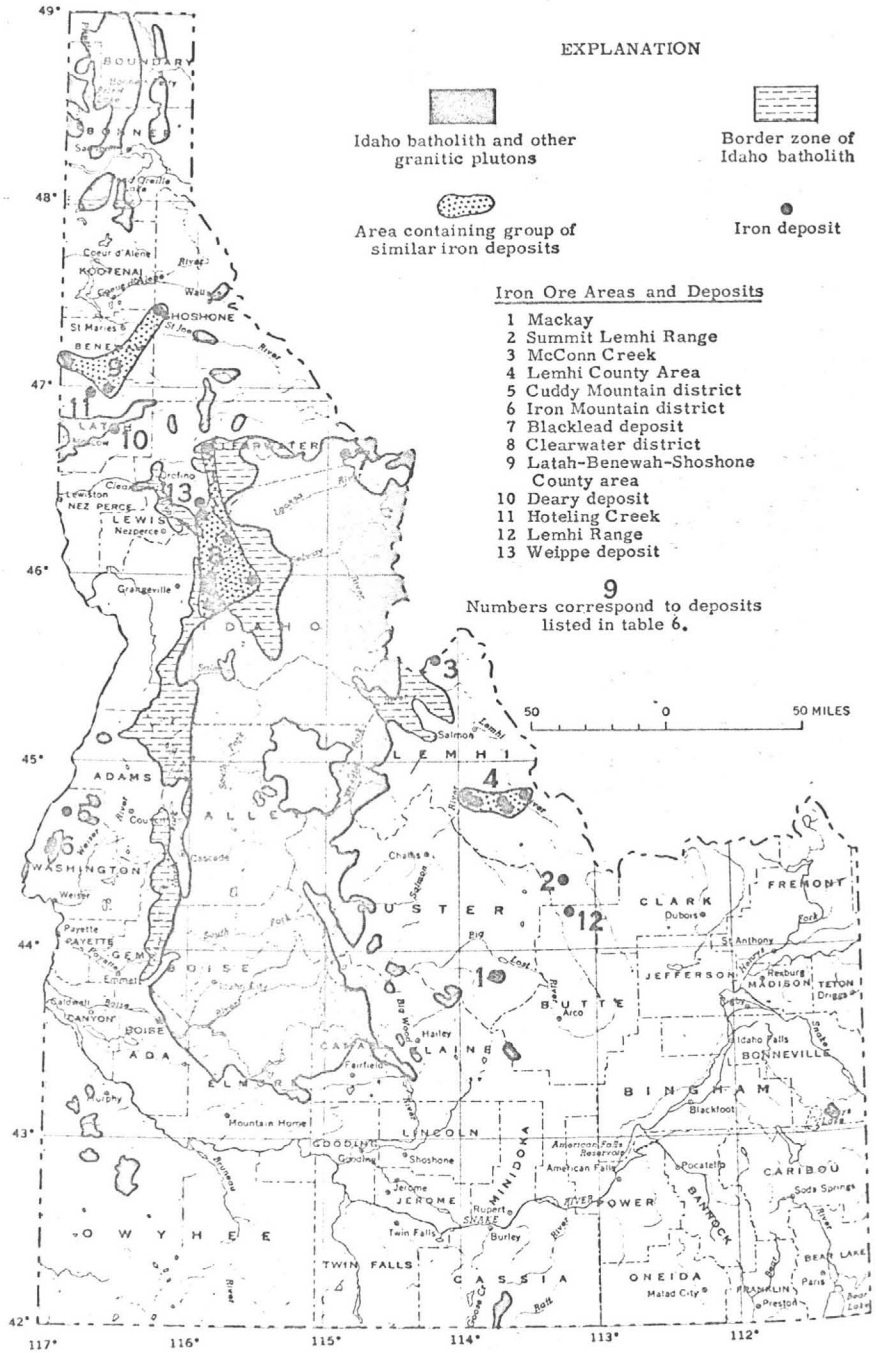

FIGURE 25.—Iron ore areas and deposits in Idaho.

ington County plus Benewah, Latah, and Shoshone Counties, 3 million tons.

Several factors deter development of an iron industry in Idaho. Among these is the relatively small size of most of the deposits, the distance from steel plants, and the lack of adequate supplies of good coking coal. Exploitation of small deposits of a few hundred thousand to a few million tons is seldom feasible unless the ore is suitable for and within economic transportation limits of an established iron or steel plant. It is possible that with increased demands for iron and steel, some of the Idaho deposits might supply raw material for iron and steel plants in Utah, and some of the higher grade deposits might supply ore for specialized uses. Idaho's presently known reserves of iron ore are relatively small but probably could be increased substantially by further exploration.

LIMESTONE AND RELATED MATERIALS

(By C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Lime-bearing rock production in the United States annually exceeds 450 million short tons. This is more than any metallic mineral produced and is exceeded in volume only by coal, sand, and gravel, and by water. There are virtually no substitutes for lime products in chemical and industrial usage.

Products manufactured from calcium and magnesium limestones are far too numerous to list here; for lime alone, there are over 7,000 uses (Lamar and Willman, 1938). Specific limestone uses, however, fall under the general categories: (1) calcium and calcium compounds, (2) cement and lime, and (3) dimension, crushed, and broken stone.

The largest volume of lime rock is used as crushed and broken stone for road aggregate and railroad ballast; significant amounts are also used in the manufacture of cement and lime, in the smelting of metals, and in agriculture.

In 1962, over 460 million tons of limestone and dolomite were produced with a value of about $650 million (Cotter and Jensen, 1963). Cement and lime products valued at approximately $1.3 billion were manufactured from some 102 million tons of this limestone (U.S. Bureau of Mines, 1963).

Limestones, including dolomitic rock, are composed of variable amounts of calcium-, magnesium-, manganese-, and iron-carbonates. These materials, originating from chemical precipitation and biological reactions are deposited as sediments chiefly in lakes, shallow seas, streams, or springs. When subjected to further natural changes, particularly pressure and temperature variations, lime-bearing rocks may become more crystalline.

For most purposes, and particularly where chemical composition is not important, moderately hard, massive limestone or magnesian limestone is desirable. For dimension stone, workability, color, texture, and hardness are the most important considerations. Attractive colors, banding (travertine or cave deposits), or the presence of shell structures (coquina), and the quality of taking a high polish (marble) may result in premium building- or trim-stone. For use in chemical,

metallurgical, and most nonconstruction uses, the calcium content, calcium to magnesium ratio, and the absence of impurities are critical, as shown on table 7.

TABLE 7.—*Commercial limestone classification*

[Range of composition rounded to nearest percent]

Rock type	Principal minerals		If dolomite present	Range of principal compounds		
	Calcite $CaCO_3$	Dolomite $Ca,Mg(CO_3)_2$	Magnesium carbonate $MgCO_3$	Calcium oxide CaO	Magnesium oxide MgO	Carbon dioxide CO_2
Supercalcium limestone	98-100	0-2	0-1	56	0-Trace	44
High-calcium limestone	95-98	2-5	1-2	55-56	Trace-1	44
Limestone	80-95	5-20	2-9	51-55	1-4	44-45
Magnesian or dolomitic limestone	54-80	20-46	9-21	44-51	4-10	45-46
High-magnesian limestone or dolomite	0-54	46-100	21-46	30-44	10-22	46-48

General specifications for various uses are listed below (percent):[1]

Cement:

Upper limits: SiO_2 17 percent; Al_2O_3, 5 percent; Fe_2O_3, 3 percent; MgO, 5 percent; K_2O+Na_2O, 1 percent; P_2O_5, 1 percent.

Lower limits: $CaCO_3$, 72 percent; $SiO_2+Fe_2O_3$ 20 percent.

NOTE.—May use blast furnace slag, or shale for source of SiO_2 and Al_2O_3 additives. $CaSO_4$ 2 to 3 percent added to clinker as retarder before grinding; source may be gypsum.

Flux, etc.:

Bessemer—Upper limits: S, 0.5 percent; P_2O_5, 0.01 percent.

Blast furnace charge—Upper limit: $MgCO_3$ 20 to 30 percent; $Al_2O_3+Fe_2O_3$, 4 percent; SiO_2, 3 to 4 percent.

Patching and lining—Lower limits: $MgCO_3$, 35 percent.

Open hearth—Upper limits: $MgCO_3$, 20 percent; SiO_2, 1 percent; S, 1 percent; P_2O_5, 1 percent.

Glass: High-calcium, low calcium or magnesian limestone low in Fe, S, and P_2O_5.

Calcium carbide: Highest purity $CaCO_3$, 97+percent; upper limits SiO_2, 1.2 percent; Al_2O_3 and Fe_2O_3, 0.5 percent; MgO, 0.5 percent; P_2O_5, 0.01 percent.

Nonhydraulic limes:[2]

Upper limits—High-calcium, $MgCO_3$, 6 percent; low magnesian, $CaCO_3$, 68 to 95 percent; high magnesian, $CaCO_3$ 54 to 72 percent.

Lower limits—High-calcium, $CaCO_3$, 91 percent; low magnesian, $MgCO_3$, 5 to 29 percent; high magnesian, $MgCO_3$, 28 to 46 percent.

Hydraulic limes: Low—Carbonates, 91 to 97 percent; other,[3] 3 to 9 percent. Moderate—Carbonates, 84 to 91 percent; other,[3] 9 to 16 percent. High—Carbonates, 77 to 84 percent; other,[3] 16 to 23 percent.

"Natural cement rock" is limestone that contains the proper proportions of clay, silica, and iron impurities so that upon burning in a kiln portland cement is produced. Cement may be produced also by adding these materials to limestone and several kinds of rocks, or commonly a shale rock of the right composition will serve as a single additive. Relatively high silica content is permissible for cement and some other products, but magnesium oxide content usually should be less than 5 percent for most limestone uses (table 7).

Dolomitic or magnesian limestones or high-magnesian limestones (dolomites) may be used to manufacture magnesium metal, high-magnesian lime, magnesium compounds, or refractories. Both magnesian limestone and limestone, when ground to the proper size (40 percent below 60 mesh screen), are now being used extensively as natural soil conditioners in place of prepared lime.

[1] Information from several published sources, including Illinois State Geological Survey Report Inv. 49.
[2] Less than 3 other constituents.
[3] Principally $SiO_2+Al_2O_3$.

The potential value of lime-bearing rock is determined by its chemical and physical characteristics and its accessibility and proximity to suitable markets. Any rock tentatively selected for commercial use must be carefully checked against the desired specifications for a raw material. The amount available is also an important factor. For example, a cement plant should have a limestone deposit that is large enough to last at least 20 years or more. Even a relatively small cement plant with an 889,000-barrel per year capacity will require about 48 million cubic feet of limestone to insure 20 years of operation. In addition, about 16 million cubic feet of shale for additive would be needed in proximity to the plant. A measure of the amount of limestone required in the lime industry can be obtained from the fact that approximately 1.8 tons of limestone (55 percent CaO) are required to produce about 1 ton of quicklime. Thus the availability of raw materials must be balanced against the desired production rate and life of the plant.

Deposits of commercial-grade limestone and magnesian limestone are abundant in (1) south, southeast, and east-central Idaho; (2) along the Snake River north of Weiser and south of Lewiston; (3) along portions of the Clearwater River and its tributaries; and (4) adjacent to Pend Oreille Lake in the Idaho Panhandle. Other widely distributed lime-bearing rocks are found in different parts of the State (fig. 26).

The ages of Idaho limestones and magnesian limestones range from some of the oldest to some of the youngest rock formations in the State. A few of the potentially commercial formations will be briefly reviewed. It must be remembered, however, that the physical and chemical characteristics of any limestone may vary considerably from place to place.

In north Idaho, some formations of the Precambrian Belt series have been called "limestones." Some facies may approach the composition of a natural cement rock; however, locally, the principal limy rock, the Wallace formation, carries insufficient calcium oxide to qualify as a limestone (table 7). Both this formation and the Striped Peak formation may occur locally as calcareous (limy) and magnesian (dolomitic) siltstones and argillites. Silica and alkalies in these rocks tend to be too high, in most instances, to permit their commercial use, although reportedly some of the rock has been used as fluxstone.

In south Idaho, certain facies of the Albion Range group of Precambrian age rank as high-calcium limestone. Several small quarries in the Albion Range are evidence of the past commercial use of this rock.

Most of the lower Paleozoic rocks (Cambrian through Devonian) in southeastern and east-central Idaho tend to be very siliceous, magnesian (dolomitic) limestones. High-calcium limestones are rare, but some facies may approximate the composition of common limestone locally.

Upper Paleozoic rocks, particularly the Madison Limestone of Mississippian age; the White Knob Limestone, of Mississippian to Per-

mian age; and the lower part of the Wells Formation (Darwin, Amsden, White Knob?), of Pennsylvania and Permian age, are generally some of the most widespread and purest limestones in Idaho. Of these, the Brazer (White Knob) appears to constitute the most extensive reserve of high-calcium limestone. The Brazer, Madison, White Knob, and Wells, however, all have sandstone and shale horizons. Also, these formations are locally rich in chert (silica) nodules and layers making them unfit for commercial use.

In north Idaho, the Cambrian Lakeview Limestone, adjacent to Pend Oreille Lake, ranges from common limestone to high-magnesian limestone (dolomite) and marble. These rocks have been exploited in the past for both cement and lime products. The Lakeview Limestone is readily accessible, but its wide range of composition would require careful quality control during production of the rock. This formation might provide agricultural limestone for north Idaho.

Probably of equal importance as the Paleozoic formations is the Triassic limestone in western Idaho along the Snake River and in Nez Perce, Lewis, and Clearwater Counties. This rock ranges from limestone through high-calcium limestone, and includes supercalcium limestone facies. Because of its physical qualities (color and hardness) some of this Triassic rock may have possibilities for use in commercial building, particularly as chips for terrazzo.

In southeast Idaho, Triassic lime-bearing rock is essentially noncommercial in quality.

The Jurassic Twin Creek Limestone occurs widely distributed in southwest Idaho. It tends to be somewhat arenaceous and argillaceous (silica- and clay-rich), but analyses suggest that locally much of this formation would be suitable for natural cement rock.

Cretaceous formations in southeast Idaho—for example, the Peterson, Draney, and certain facies of the Wayan—are very limy. These are dense fresh-water sediments that are locally magnesian limestones.

The Salt Lake Formation of Tertiary age contains thin beds of fine-grained limestone in southeast Idaho. Locally low in magnesium oxide, some of this rock occurs along Medicine Lodge Creek in Clark County. Travertine (banded limestone), in the same general area and of the same age, approaches a high-calcium limestone.

Travertine composed of supercalcium limestone occurs in the Fall Creek area in Bonneville County. Similar deposits of moderately large extent occur at other localities in southeast Idaho; for example, in the region southeast of Bruneau near the Bruneau River.

In the past, at least 34 out of 44 Idaho counties have produced some commercial products from limestone or magnesium limestone. Available statistics on past production, however, are inadequate because production is limited to a few enterprises and production figures are considered confidential.

Lime-bearing rock from this State has been used principally for agricultural stone, flux, cement rock, and lime (including the paper and sugar industries). Small quantities probably have been used in construction—for dimension stone and broken stone—but there appears to be no record of this use. More recently, the principal consumption of limestone in Idaho has been in the cement industry.

Two cement plants have operated within the State. One at Orofino in Clearwater County was closed, reportedly because of litigation.

The other, the plant of the Idaho Portland Cement Co., with a reported capacity of 949,000 barrels of cement per year, is in operation at Inkom in Bannock County. The Inkom plant operates at about 83 percent of capacity and utilizes approximately 178,000 short tons of limestone, from which it produces approximately 788,000 barrels of cement per year. This is a small plant by comparison to a plant in Alabama, which has a capacity of about 33 million barrels of cement per year.

Lime is used in the sugar industry, and much of it is produced by the sugar refiners for their own use. This production of "captive" lime has only recently been included in the U.S. Bureau of Mines Minerals Yearbooks. Although locally available, much of the raw limestone used for this purpose has been shipped in from adjacent States. In 1961, 46,760 short tons of lime were produced, requiring approximately 84,000 short tons of limestone. In 1962, production increased over 44 percent to 67,560 tons of lime, requiring about 122,000 tons of limestone.

In the past, the papermill at Lewiston has used about 8,500 short tons of Idaho limestone per year; however, this figure has probably been reduced because of technological changes involving reprocessing of sludge and recycling of lime.

Although large quantities of reasonably accessible lime-bearing rock are present in Idaho, the outlook for increased consumption is poor because of the absence of large local markets. Thus, no major expansion is expected unless new limestone-consuming industries should appear in the region. Any future widespread use of Idaho limestone must be accompanied by better quality controls by potential producers in order to meet a variety of possible specifications.

There is no evidence to suggest that additional cement plants are needed in the region. Therefore, the use of limestone in Idaho should increase only at a moderate rate. However, gradually increasing demand for cement commodities may increase production at the existing Idaho plant.

According to a study made in 1962 by Williams and Roby (private report), additional markets for limestone exist in the Pacific Northwest. Some of these markets could be supplied economically by north Idaho rock. The available markets and current prices cited per short ton of stone, for the different uses, were cited as follows: sugar production, $2.75; papermaking, $2.71; smelter flux, $1.40; agricultural stone, $3.50; and ornamental stone; $15. Currently the Nez Perce Indian Tribe is trying to get quarries in Lewis County into production.

Research by the University of Idaho Department of Agriculture may indicate an increased need for agricultural limestone in north Idaho.

MANGANESE

(By W. C. Prinz, U.S. Geological Survey, Washington, D.C.)

Manganese is indispensable in the production of steel and is thus essential to our Nation's economy. The chief value of manganese is as a desulfurizer, and more than 13 pounds are consumed in the production of each ton of steel. Some is also used as an alloying metal in high-strength steels. More than 95 percent of the manganese consumed in the United States is for metallurgical purposes; the remainder is used, generally as oxide ore or concentrate, as the depolarizer in dry-cell batteries, in the manufacture of manganese chemicals, as a drying agent in paints and varnishes, as a pigment or to neutralize the effects of iron in glassmaking and ceramics, and in the leaching of uranium ores.

Manganese occurs in a variety of minerals in the earth's crust, but insofar as ore deposits are concerned only two types are important: (1) the numerous manganese oxide minerals, and (2) the manganese carbonate, rhodochrosite. Some manganese deposits are sedimentary in origin; others are in veins or replacement deposits that formed from hydrothermal solutions or less commonly, from hot spring waters. Later action by ground water has modified many deposits of both types by converting rhodochrosite and manganese silicates to manganese oxide minerals, changing original oxide minerals to different oxide minerals, and enriching or concentrating manganese.

Most of the manganese resources of the United States are in low-grade sedimentary deposits which are not economical to mine at the present time. Domestic reserves of high-grade manganese ore are limited, and the United States therefore relies heavily on imported manganese ores to supply its annual needs of about 2 million tons. The largest domestic production of high-grade ores and concentrates (+53 percent manganese) in recent years occurred in the 1950's under the stimulus of Government purchasing at premium prices for stockpiling. Annual domestic production in 1956, 1957, and 1958 exceeded 300,000 tons, but after Government purchasing ceased, domestic production declined sharply and in 1962 amounted to only 24,758 tons, most of which came from Montana.

Idaho is not a large manganese-producing State. According to Idaho Bureau of Mines and Geology Bulletin 18 (p. 68), the State has yielded a total of approximately only 12,000 tons of manganese ore, which is less than 1 percent of our annual consumption since the first recorded production in 1926. No manganese has been produced in Idaho since the Government stopped buying ore for stockpiling in the late 1950's. Most of Idaho's manganese ore has come from two areas—one near Cleveland in Franklin County (formerly part of Bannock County) (fig. 27, No. 1) and the other at Lava Hot Springs in Bannock County (No. 2).

Manganese was first found in the Cleveland area in 1922 (Hewett, 1928). There, beds as thick as 4 feet and irregular zones of soft earthy manganese oxides with or without hard high-grade manganese oxide nodules occur in unconsolidated clay, sand, and marl several hundred feet above the floor of the valley of the Bear River (Hewett, 1928; Hewett and others, 1956, p. 204). The sediments accumulated in lakes that filled the valley in early Pleistocene time. Some manganese oxides also occur on the uneven surface of the older rocks at the base of the unconsolidated sediments. Ore from the deposits contained 30 to 49 percent manganese. The presence nearby of manganese-bearing travertine cones suggested to Hewett and Fischer (1960, p. 37) that the manganese in these deposits was deposited from hot spring waters. Vincent and Holmes (1952) have

STONE AND CONSTRUCTION MATERIALS

(By R. R. Asher, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Stone and construction materials are highly important commodities to industry in the United States. For example, crushed stone is exceeded only by the fuels, iron ore, and cement in value of annual production. Dimension stone, of lesser importance than crushed stone, has a much higher unit value; in 1961 only 0.3 percent of all stone produced in the United States was dimension stone, but it contributed 9.2 percent of the total value (Cotter and Jensen, 1962). Other stone and construction materials of importance are slate, pumice, pumicite, volcanic cinder, diatomite, and naturally expandable materials such as bloating clays and shales, perlite, and vermiculite. The value of pumice, pumicite, and volcanic cinder produced in 1961 was in excess of $6 million; volcanic cinder, of much lower unit value than pumice or pumicite, accounted for 62 percent of the tonnage produced but only for 38 percent of the gross value (Hartwell and Schreck, 1962a). The total value of crude perlite produced in the United States in 1961 was $1.5 million; the corresponding figure for expanded perlite was $12 million (Hartwell and Schreck, 1962b). It is obvious that stone and construction materials contribute significant amounts to the economy of the United States.

Crushed stone, pumice, and volcanic cinder are produced in Idaho, and until 1963 perlite was produced. There are large deposits of pumicite but there has been no production; slate occurs but its economic potential is not known; dimension stone has been produced in the past but is now an insignificant industry. Such materials as expanded clay and shale or vermiculite are not important in Idaho and they are not discussed in this chapter. Diatomite is covered in a separate chapter of this report.

Crushed stone is used in the construction industry for road stone and concrete aggregate; dimension stone finds use in building construction as interior and exterior trim and facing stone, base plates, and structural stone; it is also used for monuments and statues. Slate is used for roofing and for other specialized applications. Natural and expanded lightweight materials are used as aggregate in lightweight masonry concrete, plaster, stucco, and mortar and as aggregate in precast concrete products; they also find application as loose fill insulation, and as ingredients of manufactured wall board and acoustical tile. In addition, pumice and pumicite are used as pozzolans and volcanic cinder is used as aggregate, road metal, and railroad ballast.

The above commodities are not only important in the construction industry; they are used in many other fields. The lightweight materials mentioned above can be used as inert mineral fillers, filter aids, paint extenders, abrasives, soil conditioners and for many other uses (Otis 1960a, 1960b). Crushed stone, particularly limestone, the most important raw material of the crushed stone industry, has a wide range of application. Limestone is a basic ingredient in cement manufacture, and it is important to agriculture and the chemical and metallurgical

industries. Because of its importance, limestone is discussed in a separate chapter of this report.

In general, almost any type of rock is suitable as crushed stone for construction uses as long as it is relatively strong, abrasion resistant, and chemically inert (Severinghaus, 1960). The size and shape of the deposit and the amount of overburden are important cost items in quarry site selection (Key 1960). Once a quarry is developed, distance from point of use is generally the limiting economic factor. Because raw materials are readily available at many localities and portable crushing plants can be readily moved to new sites, a quarry is generally abandoned and a new one established when the distance from a construction site becomes excessive. In some applications, such as limestone or quartzite for chemical or metallurgical uses, chemical composition may be more important than the physical characteristics of the product. The availability of chemically suitable stone may strongly influence the selection of a site for the development of an industrial plant.

Like crushed stone, almost any type of rock may be used for dimension stone, but deposits are much more restricted because of the rigid specifications covering uniformity of texture and grain size, constant color or color patterns, and freedom from impurities that cause staining or deterioration. Porous rocks are unsuitable because of adverse effects on durability. Because relatively large blocks are required, stone with closely spaced joints or other planes of weakness are unacceptable (Bowles, 1960). The limited availability and the expense in mining, handling, and shipping these heavy, bulky products make dimension stone uncompetitive in many applications. Substitute materials such as concrete products and other manufactured items have largely replaced it in the construction market (Key 1960), but the use of ornamental and decorative stone is an important market that has been increasing in recent years. Stone possessing some unique quality may be highly valued for special monumental or architectural applications and it can then be shipped long distances.

Slate, like dimension stone, has a limited market. Roofing slate was at one time very popular, but manufactured products have now largely displaced it from the roofing market. Slate is used in the manufacture of billiard and other table tops, electric panels, blackboards, and flagstones. Crushed slate is used for roofing granules. Slate expanding processes have been developed and expanded slate is used for lightweight aggregate (Key, 1960).

Pumice, pumicite, and volcanic cinder are frothy, cellular volcanic ejecta produced by explosive volcanic activity. They are composed chiefly of volcanic glass and characterized by a low bulk density because of their cellular nature. These materials are found in areas characterized by recent volcanic activity on the slopes of volcanic cones, as bedded deposits resulting directly from ash falls, often interbedded between lava flows or welded tuff sheets, and as sedimentary deposits associated with clays, sands, and silts. Pumicite may be carried long distances by air currents following an eruption and

be deposited some distance from its source. Commercially valuable deposits of these glassy volcanic materials older than Tertiary are rare as volcanic glasses tend to devitrify rapidly.

Pumice and pumicite are acidic in composition, similar to rhyolite; pumicite is the fine material produced by violent volcanic activity and pumice is the coarser fraction. Cinders are the basaltic or basic equivalent of pumice.

The chief use of pumice is for lightweight aggregate, and as such it must be composed of strong, clean granules or fragments with small, evenly distributed vesicles that are not interconnected. Proper size gradation of the material to be used for aggregate is important, and crushing and screening may be required to produce a suitable product. Freedom from reactive chemical impurities and from soil, humus, clay, and the like are other requirements. Pumice must produce a workable mix with a low water requirement and produce concrete with a high strength-to-weight ratio in order to be used.

Volcanic cinders to be used for aggregate must possess qualities similar to those given for pumice. For road aggregate or railroad ballast, the chief uses of cinders, the particles must be strong and of the proper size and shape.

The chief use of pumicite is for pozzolan. A pozzolan is a siliceous, or siliceous and aluminous substance, used as a partial replacement of the cement (10 to 30 percent) in a concrete mix. It imparts certain desirable features to the mix and to the concrete. The material used for pozzolan must occur as extremely fine particles or grinding will be required; calcining may be necessary to induce or increase the pozzolanic activity of a material and the optimum calcining temperature must be determined. The pozzolan should effectively control alkali-aggregate reactions between cement and alkalies, improve workabililty, reduce heat generation, thermal volume change, bleeding, and permeability of concrete. It should not greatly increase the water requirement in the mix, contain any exchangeable alkalies, or materially affect the strength or setting time of the concrete (U.S. Bureau of Reclamation, 1955).

Perlite, like pumice, is a variety of acidic volcanic glass, but it lacks the cellular structure of pumice and contains from 2 to 5 percent combined water. In general, perlite is thought to be produced through the hydration of obsidian, a variety of volcanic glass containing up to 1 percent combined water, but the source of the chemically combined water in perlite and the mechanism of its introduction are not well understood (Sharps, 1961). Because volcanic glass results from the rapid cooling of magma, perlite deposits are associated with acidic lava flows, volcanic domes, and intrusive bodies emplaced at shallow depths. Because volcanic glass is unstable and devitrifies rapidly, exploitable deposits older than Tertiary are seldom found.

In petrography the term "perlite" refers to a peculiar onionskin or concentric strain pattern developed in volcanic glass. This texture

is diagnostic of perlite. Commercial perlites, when heated beyond a certain temperature, expand to yield a lightweight, frothy product that is used as aggregate in gypsum plaster and concrete, as a filter aid, and for other uses; but the presence of perlitic structure does not necessarily indicate an expandable material.

In evaluating a perlite deposit, the softening temperature and fuel requirements must be considered as well as the expansion characteristics of the material; percent decrease in bulk density when expanded, chemical and physical variations of the material in the deposit, and the amount of included nonexpandable material are important considerations. The body strength of the expanded particles is important, and light-colored, spherical particles with thick cell walls are desirable.

It should be pointed out that in all of the commodities discussed above, distance from markets and transportation facilities are extremely important economic factors. These are low unit value products that cannot be profitably exploited if excessive transportation costs are encountered. Thus, even though stone and construction materials of excellent quality may be found, they are of little value in remote localities. The materials used in the construction industry are in a highly competitive market and a deposit with an economic disadvantage cannot compete.

World production figures are incomplete for the stone industry, but in 1961 the United States was well ahead of any other country for which figures are available.

In 1961 Idaho ranked about 40th among the States producing stone with a reported production of 1.9 million tons, all crushed stone. Approximately 80 percent was basalt and granite for construction uses and 20 percent was limestone and quartzite for cement manufacture, construction, metallurgical, and industrial uses. There was no reported production of dimension stone but it is likely that there were a few small local quarries operating intermittently in the State that produced an unreported tonnage.

The recorded production of stone in Idaho goes back many years, the amount varying in response to demands by the construction, cement, and other industries. Dimension stone has been produced at various times but there has never been a significant, sustained production. The greatest demand for crushed stone in Idaho occurred in 1954 during construction of Palisades Dam in the southeastern part of the State. The accompanying graph (fig. 47) shows the production of crushed stone in Idaho for the period 1951–62. Production figures were taken from the U.S. Bureau of Mines Minerals Yearbooks for the various years.

Table 13 summarizes the important features of Idaho's stone industry. The map number is the number following the location of a deposit; it refers to the corresponding number on figure 48 to aid in locating the deposit. Many of the deposits and quarries can be located only approximately.

35-920 O—64——14

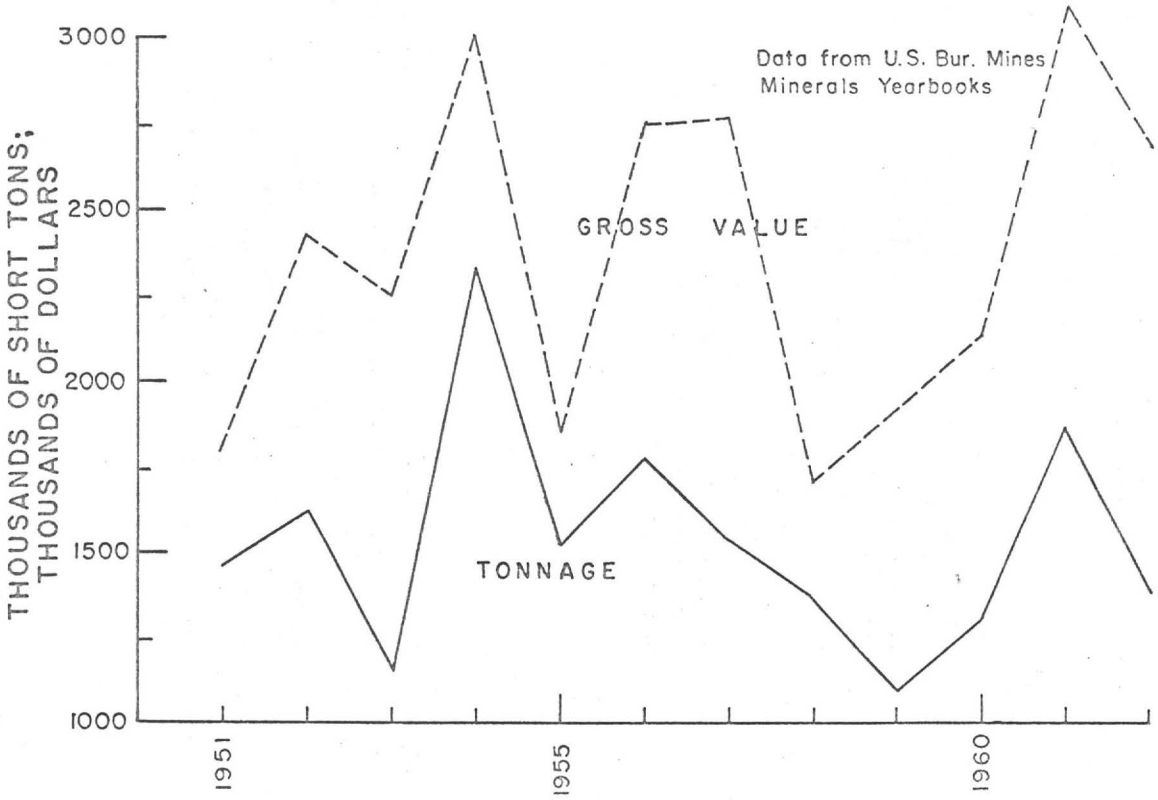

FIGURE 47.—Stone production in Idaho, 1951–62.

TABLE 13.—*Important features of Idaho's stone industry*

Rock type	Uses	Location of deposits and map No.	Remarks
Basalt	Aggregate and roadstone; used in past as building stone locally.	Widespread; outcrop areas of Snake River Group and Columbia River Basalt. Fig. 48 shows areal extent of basalt in Idaho.	Quarries too numerous to plot individually. Located near roads in areas where basalt available. Most basalt suitable but must avoid stone that is too brittle, soft, or contains reactive chemical ingredients.
Granite	Aggregate and roadstone; building and monumental stone in past.	Roadstone quarries located randomly wherever granitic rocks occur near roads, individual quarries too numerous to plot individually. Building stone quarried in past near head of Hulls Gulch 5½ miles east of Boise (G-1) (Loughlin, 1914); in T. 55 N. R. 3 W. in Bonner County (G-2); reportedly granite of excellent quality for monumental stone occurs along Snake River 25 miles above Lewiston (G-3) (Loughlin, 1914).	Many of the granitic areas in Idaho are remote and difficult of access. Close jointing, weathering, and disintegration makes much of the granite unsuitable. Rocks occurring in gneissic border zone of Idaho batholith have potential value as trim and facing stone.
Rhyolites, Tuffs, and Andesites.	Used for building stone in past	Occur in Tertiary silicic flow rocks and associated tuffaceous rocks of southern Idaho, see fig. 48. Locations of individual quarries not known except 1 in Germer Tuffaceous Member of Challis Volcanics, near Challis, Custer County (R-1).	Tuffs are easily quarried and worked; they harden on prolonged exposure (Behre, 1930, Savage, 1961). Flow rocks potentially valuable as trim stone because of attractive colors and intricate flow patterns.
Slate, Marble, Sandstone, Quartzite, and Shale.	Building stone; industrial and metallurgic uses.	Building stone, Bonner County, from rocks of Belt Series (B-1). Quartzite for industrial uses, southeastern Idaho, one quarry located near Soda Springs, Caribou County (Q-1); locations of other quarries not accurately known. Quartz quarried in Bonner County for flux in ferroalloy plant located in Spokane, Wash. (Q-2). Slate of pleasing reddish color reported near Cottonwood, Idaho County (S-1), (Louglin, 1914). Marble suitable for monumental stone reported 25 miles south of Lewiston on Snake River (M-1), at Basin in Cassia County (M-3) and near Orofino in Clearwater County (M-4) (Loughlin, 1914). Sandstone quarried near Table Rock southeast of Boise, Ada County (Ss-1). Sandstone of good quality near Dingle, Bear Lake County (Ss-2).	Sandstone of Idaho Formation from Table Rock quarry important in early 1920's; used in construction of State Capitol in Boise and shipped to California, Nebraska, Colorado, Nevada, Oregon and Washington (Savage, 1958). Other localities only of local importance.

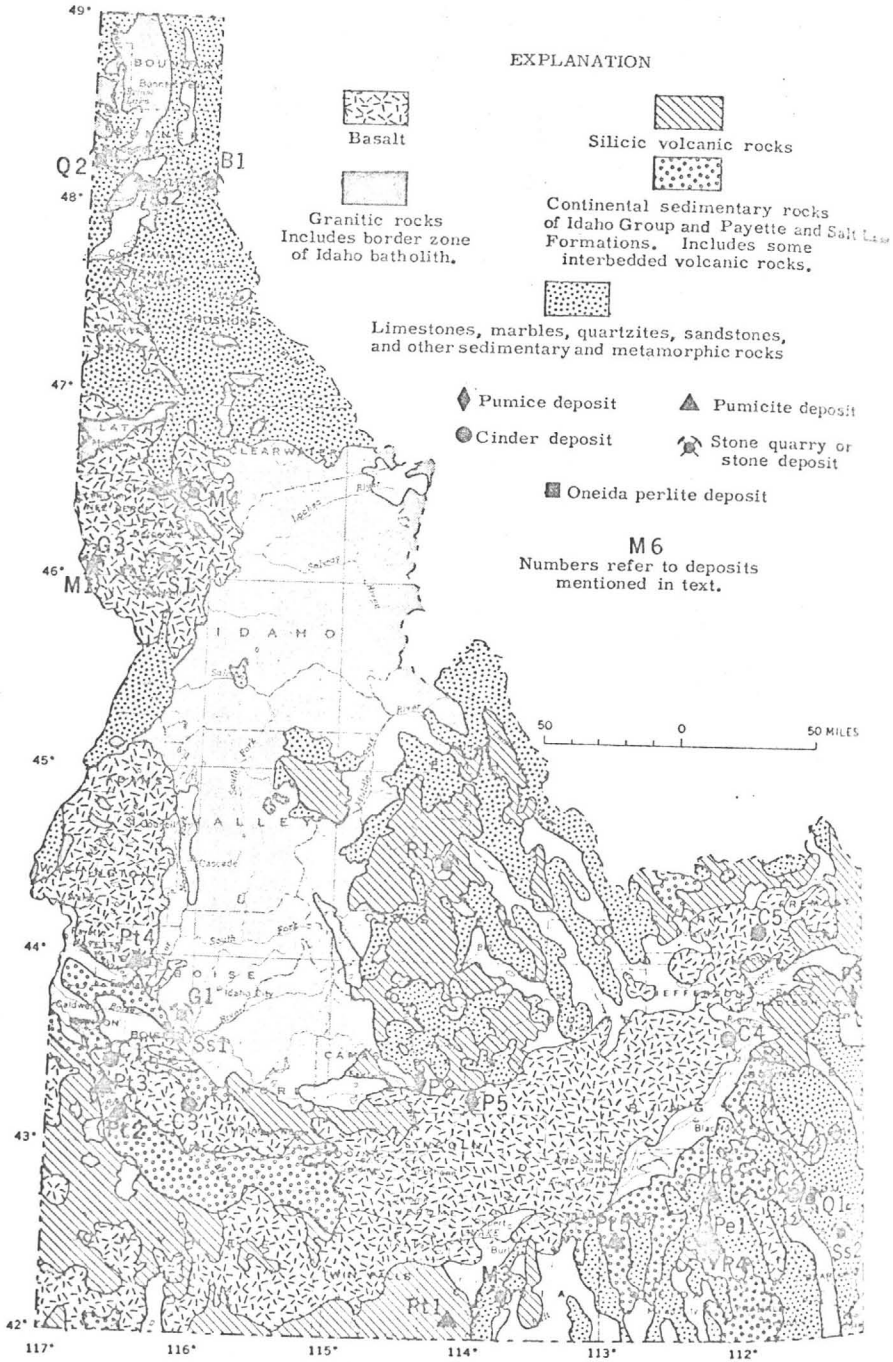

FIGURE 48.—Stone and construction materials in Idaho.

Idaho has sufficient reserves to satisfy demands for crushed stone for many years. Consumption will probably increase in the future as there are several Federal highway construction projects, dams, and other construction jobs now underway and planned in the State. There is little chance that a large, prosperous dimension stone industry will develop in Idaho. A market could be developed for many of the sandstones, rhyolites, and tuffs with pleasing colors and unusual textures for trim, facing, and ornamental stone, however. There are small areas of shale and slate in the State that have potential value in the manufacture of expanded products for lightweight aggregate; this use has never been evaluated.

Idaho ranks about seventh among the States producing pumice, pumicite, and volcanic cinder. In 1946 Idaho was in first place as a producer of pumice but since then Idaho production has generally decreased while overall U.S. production has increased. The graph in figure 49–A shows Idaho production of pumice, pumicite, and volcanic cinders from 1946 to 1962 and it points out how the annual tonnage and value of these products has declined. The data for the graph were taken from the U.S. Bureau of Mines Minerals Yearbooks for the various years. Prior to 1963 volcanic cinders were not included in the annual figures prepared by the U.S. Bureau of Mines, and the portion of the graph representing the years 1946 to 1953 shows only pumice and pumicite. There is an unknown quantity of cinders produced in Idaho each year that are not reported in the U.S. Bureau of Mines for inclusion in their annual figures. A less drastic decline in Idaho production would be indicated by the graph if these unrecorded cinders could be included.

Figure 49–B is a table comparing total U.S. production and Idaho production of pumice, pumicite, and volcanic cinders. This table shows that while U.S. production has been increasing yearly, Idaho production has generally decreased, especially since 1958. Cinders contribute significantly to overall U.S. production but many of the cinders produced in Idaho are unrecorded; thus figure 49–B is not a true picture of the situation, but it is indicative. Loss of out-of-State markets to producers more favorably situated and to competing products has caused Idaho pumice production to decline. Increasing freight rates, coupled with a decreasing unit value for pumice and depletion of easily accessible deposits close to rail facilities, are also adverse factors affecting production.

There has been no significant production of pumicite in Idaho. This material is widely available and a potential market exists for it as a pozzolanic material and for other uses. Cinders are an important commodity; they are used largely by noncommercial firms such as Federal, State, and county agencies for road aggregate. Only two commercial cinder pits are known in the State.

Pumice and pumicite are associated with the Salt Lake and Payette formations, and Idaho group of southern Idaho. The areal extent of these units is shown on figure 48. Cinders are associated with the Snake River basalts and cinder cones are abundant on the Snake River Plain and in adjacent areas. Waterlaid cinders are found interbedded with sediments in Ada, Canyon, and Bonneville Counties. Because cinders and pumicite are so widespread and abundant, only the more important and extensive deposits are shown on figure 48.

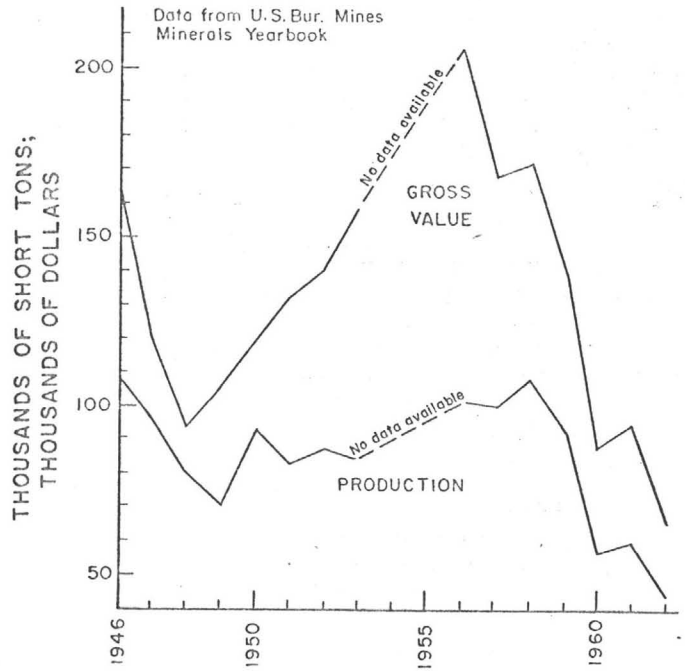

FIGURE 49-A.—Pumice, pumicite, and volcanic cinder production in Idaho, 1946–62.

YEAR	1946	1947	1948	1949	1950	1951	1952	1953	1954
U.S.	319.9	442.6	607.7	716.7	719.4	749.9	597.0	1,348.1	1,647.4
IDAHO	108.8	98.6	79.4	71.4	94.0	83.5	88.1	85.2	No Data Available
YEAR	1955	1956	1957	1958	1959	1960	1961	1962	
U.S.	1,804.5	1,482.0	1,827.0	1,973.0	2,276.0	2,212.0	2,463.0	2,249.0	
IDAHO	No Data Available	101.9	100.2	108.0	93.0	56.0	60.0	43.0	

Data from U.S. Bur. Mines Minerals Yearbooks

FIGURE 49-B.—Comparison of United States and Idaho pumice, pumicite, and volcanic cinder production, 1946–62, in thousands of short tons.

Table 14 is a general summary of the features of the known pumice deposits in Idaho and of selected, representative deposits of pumicite and cinders.

Reserves of pumice, pumicite, and volcanic cinders are abundant and sufficient to meet demands for many years. Economic factors hinder development of the deposits.

The Oneida Perlite Corp., with a deposit about 25 miles north of Malad in Oneida County (Pe–1, fig. 48), mined, milled, and expanded

TABLE 14.—*Summary of the features of pumice, pumicite, and cinder deposits in Idaho*

Commodity	Areas of occurrence	Important deposits and representative occurrences	Remarks
Pumice (most deposits contain associated pumicite).	Southeastern Idaho; associated with Salt Lake Formation and with Tertiary silicic volcanic rocks.	1. Foothills east of Ammon, Bonneville County; part of Salt Lake Formation. (P–1.)	1. Ammon and vicinity most important producing area in State; product sells for $1.65 to $2.30 per ton.
		2. Magic Reservoir pumice; associated with Tertiary extrusives; probably near a volcanic vent. (P–2.)	2. Development by various firms attempted several times, presently inactive; large reserves; pumice is coarse, requires crushing, good quality.
		3. Tetonia pumice, near village of Tetonia in Teton County; Salt Lake Formation? (P–3.)	3. Similar to pumice mined near Ammon. Reserves extensive. Deposits only slightly developed: intermittent production.
		4. About 20 miles north of Malad, Oneida County. Salt Lake Formation. (P–4.)	4. Associated with perlite and rhyolitic flows. Pit operated by Hess Construction Co. of Malad. Crushed, screened, blended product sells for $2.50 per ton, marketed in Utah. Reserves extensive.
		5. Between Carey and Picabo, Camas County; interbed in Challis volcanics (?). (P–5.)	5. Deposit undeveloped; reserves unknown, possibly substantial.
Pumicite	Southern Idaho; associated with sediments of Payette Formation, Idaho Group and Salt Lake Formation.	1. East flank of Cassia Mountains, Goose Creek Basin, Cassia County. Salt Lake or Payette Formations. Interbedded with acidic extrusive rocks. (Pt–1.)	1. Fairly pure ash with a total thickness of 1,700 feet; areal extent in excess of 100 square miles (Piper, 1923; Anderson, 1931); undeveloped.
		2. South of Murphy, Owyhee County, along Rabbit Creek; Idaho Group. (Pt–2).	2. Deposit extensive, ash occurs in horizontal bed 12 feet thick, material indurated but friable; pure volcanic ash; undeveloped.
		3. Along Reynolds Road, southwest of Walters Ferry, Owyhee County; Idaho Group. (Pt–3.)	3. Very extensive deposits of volcanic ash about 60 feet thick, ash forms steep cliffs, beds about horizontal; undeveloped.
		4. North of Emmett, Gem County; Idaho Group. (Pt–4.)	4. Extensive deposit, in dipping beds; overburden of sand, silt. Some testing done, indicates suitability of the ash as pozzolan.
		5. Near Rockland, Power County; Salt Lake Formation. (Pt–5.)	5. Occurrences numerous, some up to 150 feet thick; undeveloped.
		6. Near Inkom, Bannock County; Salt Lake Formation. (Pt–6.)	6. Pit developed by Idaho Portland Cement Company for use in manufacture of portland-pozzolan cement. Beds of ash total 200 feet in thickness. Fairly hard, requires grinding; reserves abundant.

TABLE 14.—*Summary of the features of pumice, pumicite, and cinder deposits in Idaho*—Continued

Commodity	Areas of occurrence	Important deposits and representative occurrences	Remarks
Volcanic cinders	Southern Idaho; cinder cones are abundant on Snake River Plain. Waterlaid accumulations can be found in Ada, Canyon, and Bonneville counties.	1. L. Freiberghaus Pit, about 10 miles south of Nampa, Canyon County, waterlaid cinders. (C-1.) 2. Near Soda Springs, Caribou County; cinder cones numerous on Blackfoot lava field. (C-2.) 3. Numerous State and county pits at many places in southern Idaho, too numerous to mention individually. Examples are Cinder Cone Butte, Ada County (C-3); Shattuck Butte, Bonneville County (C-4); cones in Mud Lake region (C-5); and many others.	1. Pit developed in waterlaid cinders in recent sediments; reportedly cinders are 120 feet thick. Operated by L. Freiberghaus, Nampa. Cinders marketed locally for surfacing and aggregate. 2. Several State and county cinder pits developed. One commercial pit operation, cinders sold in Utah markets as lightweight aggregate. 3. Those cones near roads generally have been exploited for cinders.

perlite from November of 1960 until 1963; no figures are available on the quantity produced during this period. A mill is maintained at the mine; an open pit operation and expanding facilites are located on the railroad at Malad (Staley, 1962). The deposit is associated with Tertiary silicic volcanic rocks overlying the Salt Lake Formation that locally contains pumice. Perlite has not been produced from any other deposit in Idaho, and none of sufficient size are known. Small lenses of perlitic glass can be seen in the Tertiary silicic volcanic rocks at several places in southern Idaho but these occurrences are not of commercial interest.

A report on the volcanic construction materials in Idaho is being prepared by the Idaho Bureau of Mines and Geology. The report will include more details on the location, geology, quality, and quantity of the various materials within the State.

THORIUM AND THE RARE EARTHS

(By A. L. Anderson and C. N. Savage, Idaho Bureau of Mines and Geology, Moscow, Idaho)

Thorium and the lanthanide series of elements ("rare earths") have similar chemical properties and commonly occur in the same minerals. Thorium is not quite as plentiful in the earth's crust as lead and molybdenum but is more plentiful than uranium. It is radioactive, and its possible use as a nuclear energy fuel might significantly increase demand for thorium ores. The rare earths are not radioactive but are somewhat like aluminum and are essentially basic in character. Their future lies in their remarkable versatility. Some of these little-known elements are as plentiful as copper, lead, and zinc, and others, although scarce, are more abundant than mercury, silver, and selenium. Markets for the thorium and rare-earth minerals are now relatively small. In part, this reflects the relatively high unit cost of production of limited quantities. If larger markets existed, volume production techniques might substantially lower unit costs. Potential uses are being developed that may create increased demand, which, in turn, should lead to lower prices and foster further expansion.

At present, thorium (Th) is used primarily as thorium dioxide (ThO_2) containing 1 percent cerium dioxide (CeO_2) for use in the incandescent gas mantle devised by Welsbach for kerosene and gasoline lanterns. Other uses of thorium and its compounds are as catalytic agents in the petroleum and chemical industries; as ingredients in special glasses, medicinal compounds, and polishing compounds; as a refractory; as an alloying material with magnesium, and in electronic devices. The potential use of thorium as a source of atomic power, although still in the experimental stage, has some advantages over uranium according to some investigators. Thorium cannot be used directly in nuclear reactions but can be converted to fissionable U^{233} in so-called breeder reactors, and the U^{233} is then used as a source of atomic energy. Experimental reactors using thorium cores are now in operation, while research is being done all over the world to further the use of thorium as a source of energy.