Changes in Stratigraphic Nomenclature by the U.S. Geological Survey 1966

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CONTRIBUTIONS TO STRATIGRAPHY

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CHANGES IN STRATIGRAPHIC NOMENCLATURE BY THE U.S. GEOLOGICAL SURVEY, 1966

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LISTINGS OF NOMENCLATURAL CHANGES

In the following listings, the changes in stratigraphic nomenclature are grouped together in the categories of (1) new names adopted for official use, (2) previously used names adopted for official use, (3) stratigraphic names revised, (4) changes in age designation, (5) stratigraphic names reinstated, and (6) stratigraphic names abandoned. The stratigraphic names involved in change are listed alphabetically under each category. The age of the unit, the area in which the name is employed, the title of the report, and the publication in which the change is described are given. The capitalization of age terms in the age column follows official usage.

NEW NAMES ADOPTED FOR OFFICIAL USE IN U.S. GEOLOGICAL SURVEY REPORTS

Name	Age	Location	Report in which new name is adopted: Title and authorship	Report in which new name is adopted: Publication (U.S. Geol. Survey except as indicated)	Year of publication
Alonso Formation	Late Cretaceous	Puerto Rico	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221–C	1966
Apple Ranch Member (of Word Formation).	Early and Late Permian (Guadalupe).	Texas	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Beckers Butte Member (of Martin Formation).	Early or Middle Devonian	Arizona	Devonian rocks and paleogeography of central Arizona, by Curt Teichert.	Prof. Paper 464	1965
Black Hills Glaciation	Pleistocene (Illinoian)	Alaska	Glaciation in the Nabesna River area, upper Tanana River valley, Alaska, by A. T. Fernald.	Prof. Paper 525–C	1965
Bull Fork Formation	Late Ordovician	Kentucky	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966
China Tank Member (of Word Formation).	Early and Late Permian (Guadalupe).	Texas	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Cibecue Member (of Supai Formation).	Permian and Pennsylvanian(?).	Arizona	Geologic map of the Cibecue quadrangle, Navajo County, Arizona, by T. L. Finnell.	Map GQ–545	1966
Cibuco Formation	Late Cretaceous or early Tertiary.	Puerto Rico	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244–C	1966
Cinnabar Tuff Tongue (of Fields Creek Formation of Aldrich Mountains Group).	Late Triassic(?)	Oregon	Geologic map of the Mount Vernon quadrangle, Grant County, Oregon, by C. E. Brown and T. P. Thayer.	Map GQ–548	1966
Cotorra Tuff	Cretaceous	Puerto Rico	The Malo Breccia and Cotorra Tuff in central Puerto Rico, by R. P. Briggs.	This report, p. A27	1967
Cuchillas Member (of Avispa Formation of Río Orocovis Group).	Late Cretaceous	do	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244–C	1966
Cuyón Formation	do	do	Cuyón Formation of east-central Puerto Rico, by Lynn Glover III.	This report, p. A18	1967
Dugout Mountain Member (of Skinner Ranch Formation).	Early Permian (Leonard)	Texas	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Escambia Sand Member (of Pensacola Clay).	middle and late Miocene	Florida and Alabama.	Geology of Escambia and Santa Rosa Counties, western Florida panhandle, by O. T. Marsh.	Florida Geol. Survey Spec. Pub. 5.	1964
Flor de Alba Limestone Lentil (of Pozas Formation).	Late Cretaceous	Puerto Rico	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221–C	1966
Grant Lake Limestone	Late Ordovician	Kentucky and Ohio	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966

Huachuca Quartz Monzonite	Jurassic(?)	Arizona	Huachuca Quartz Monzonite, Huachuca Mountains, Cochise County, Arizona, by P. T. Hayes.	This report, p. A29	1967
Ingle Tuff Tongue (of Laycock Graywacke of Aldrich Mountains Group).	Late Triassic(?)	Oregon	Geologic map of the Mount Vernon quadrangle, Grant County, Oregon, by C. E. Brown and T. P. Thayer.	Map GQ-548	1966
Jatahmund Lake Glaciation	Pleistocene (Wisconsin)	Alaska	Glaciation in the Nabesna River area, upper Tanana River valley, Alaska, by A. T. Fernald.	Prof. Paper 525-C	1965
Lambert Shale	Oligocene or Miocene	California	Geology of the Palo Alto quadrangle, Santa Clara and San Mateo Counties, California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Map Sheet 8.	1966
Los Negros Formation (of Río Orocovis Group).	Late Cretaceous	Puerto Rico	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244-C	1966
Los Puertos Formation (of Jacaguas Group).	early Paleocene and early Eocene(?).	do	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report, p. A29	1967
Malo Breccia	Late Cretaceous	do	The Malo Breccia and Cotorra Tuff in the Cretaceous of central Puerto Rico, by R. P. Briggs.	This report, p. A23	1967
Mameyes Formation	do	do	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221-C	1966
Matilde Formation	late Paleocene and Eocene	do	The Matilde and Milagros Formations of early Tertiary age in northwest Puerto Rico, by A. E. Nelson and O. T. Tobisch.	This report, p. A19	1967
Milagros Formation	Eocene(?)	do	do	This report, p. A22	1967
Montebello Limestone Member (of Cibao Formation).	late Oligocene and early Miocene.	do	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221-C	1966
Mucarabones Sand	middle Oligocene	do	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244-C	1966
Naashoibito Member (of Kirtland Shale).	Late Cretaceous	New Mexico	History of nomenclature and stratigraphy of rocks adjacent to the Cretaceous-Tertiary boundary, western San Juan Basin, New Mexico, by E. H. Baltz, S. R. Ash, and R. Y. Anderson.	Prof. Paper 524-D	1966
Ortiz Formation	Paleocene or Eocene	Puerto Rico	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244-C	1966
Page Mill Basalt	early or middle Miocene	California	Geology of the Palo Alto quadrangle, Santa Clara and San Mateo Counties, California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Map sheet 8.	1966
Palmarejo Formation	Paleocene or Eocene	Puerto Rico	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244-C	1966
Pensacola Clay	middle and late Miocene	Florida and Alabama	Geology of Escambia and Santa Rosa Counties, western Florida panhandle, by O. T. Marsh.	Florida Geol. Survey Spec. Pub. 5.	1964
Raspaldo Formation (of Jacaguas Group).	early Paleocene to early Eocene.	Puerto Rico	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report, p. A36	1967

NEW NAMES ADOPTED FOR OFFICIAL USE IN U.S. GEOLOGICAL SURVEY REPORTS—Continued

Name	Age	Location	Report in which new name is adopted		Year of publication
			Title and authorship	Publication (U.S. Geol. Survey except as indicated)	
Redskin Granite	Precambrian	Colorado	Geologic and geochemical features of the Redskin Granite and associated rocks, Lake George beryllium area, Colorado, by C. C. Hawley, Claude Huffman, Jr., J. C. Hamilton, and L. F. Rader, Jr.	Prof. Paper 550–C	1966
Taylor Ranch Member (of Hess Formation).	Early Permian (Leonard)	Texas	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Tetuán Formation	Late Cretaceous	Puerto Rico	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221–C	1966
Vista Alegre Formation	Early(?) to Late Cretaceous.	do	do	do	1966
Wedin Member (of Cathedral Mountain Formation).	Early Permian (Leonard)	Texas	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Willis Ranch Member (of Word Formation).	Early and Late Permian (Guadalupe).	do	do	do	1966
Yunes Formation	Paleocene to Eocene	Puerto Rico	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221–C	1966

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PREVIOUSLY USED NAMES ADOPTED FOR OFFICIAL USE IN U.S. GEOLOGICAL SURVEY REPORTS

Name	Age	Location	Original authorship	Report in which name is adopted: Title and authorship	Report in which name is adopted: Publication (U.S. Geol. Survey except as indicated)	Year of publication
Ardmore Bentonite Bed (of Sharon Springs Member of Pierre Shale).	Late Cretaceous	South Dakota and Wyoming.	Spivey, 1940	The Red Bird section, a reference locality of the Upper Cretaceous Pierre Shale in Wyoming, by J. R. Gill and W. A. Cobban.	Prof. Paper 393–A	1966
Beverly Member (of Ellensburg Formation).	late Miocene and early Pliocene.	Washington	Mackin, 1961	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224–G	1966
Campbell Ledge Shale Member (of Pottsville Formation).	Middle Pennsylvanian	Pennsylvania	White, 1883	Geology of the Ransom quadrangle, Lackawanna, Luzerne, and Wyoming Counties, Pennsylvania, by T. M. Kehn, E. E. Glick, and W. C. Culbertson.	Bull. 1213	1966
Colvos Sand	Pleistocene	Washington	Noble and Wallace, 1965.	Ground-water occurrence and stratigraphy of unconsolidated deposits, central Pierce County, Washington, by K. L. Walters and G. E. Kimmel.	Washington Div. Water Resources Water Supply Bull. 18.	1965
Corozal Limestone	Paleocene or Eocene	Puerto Rico	Berkey, 1915	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244–C	1966
Du Noir Limestone Member (of Gallatin Limestone).	Late Cambrian	Wyoming	Miller, 1936	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495–B	1966
Eastford Gneiss	pre-Pennsylvanian	Connecticut	Gregory, 1906	Geologic map of the Hampton quadrangle, Windham County, Connecticut, by H. R. Dixon and Fred Pessl, Jr.	Map GQ–468	1966
Exshaw Formation	Devonian and Mississippian.	Montana	Warren, 1937	Exshaw Formation of Devonian and Mississippian age in northwestern Montana, by C. A. Sandberg.	This report, p. A39	1967
Fort Apache Member (of Supai Formation).	Permian	Arizona	Stoyanow, 1936	Geologic map of the Cibecue quadrangle, Navajo County, Arizona, by T. L. Finnell.	Map GQ–545	1966

PREVIOUSLY USED NAMES ADOPTED FOR OFFICIAL USE IN U.S. GEOLOGICAL SURVEY REPORTS—Continued

Name	Age	Location	Original authorship	Report in which name is adopted: Title and authorship	Report in which name is adopted: Publication (U.S. Geol. Survey except as indicated)	Year of publication
Frenchman Springs Member (of Yakima Basalt of Columbia River Group).	late Miocene or early Pliocene.	Washington	Mackin, 1961	Stratigraphy of the upper part of the Yakima Basalt in Whitman and eastern Franklin Counties, Washington, by J. W. Bingham and K. L. Walters.	Prof. Paper 525–C	1965
Griswold Gap Member (of Pocono Formation).	Early Mississippian	Pennsylvania	White, 1881	Geology of the Ransom quadrangle, Lackawanna, Luzerne, and Wyoming Counties, Pennsylvania, by T. M. Kehn, E. E. Glick, and W. C. Culbertson.	Bull. 1213	1966
Guayo Formation (of Jacaguas Group).	middle Eocene	Puerto Rico	Pessagno, 1960	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report, p. A38	1967
Jacaguas Group	Late Cretaceous to middle Eocene.	do	Pessagno, 1961	do	This report, p. A29	1967
Jerome Member (of Martin Formation).	Late Devonian	Arizona	Stoyanow, 1930	Devonian rocks and paleogeography of central Arizona, by Curt Teichert.	Prof. Paper 464	1965
Joshua Rock Gneiss Member (of New London Gneiss).	Ordovician(?) or older	Connecticut	Lundgren, 1963	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull. 1224–J	1966
Keetley Volcanics	early Oligocene	Utah	Kildale, 1956	Geologic map of the Park City West quadrangle, Utah, by M. D. Crittenden, Jr., F. C. Calkins, and B. J. Sharp.	Map GQ–535	1966
Kope Formation	Late Ordovician	Kentucky and Ohio.	Weiss and Sweet, 1964	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966
LaHood Formation (of Belt Series).	Precambrian	Montana	Alexander, 1955	Geologic map and cross sections of Maudlow quadrangle, Montana, by B. A. L. Skipp and A. D. Peterson.	Map I–452	1965
Mindego Basalt	Oligocene or Miocene	California	Cummings, Touring, and Brabb, 1962.	Geology of the Palo Alto quadrangle, Santa Clara and San Mateo Counties, California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Map sheet 8.	1966

Miramar Formation (of Jacaguas Group).	Late Cretaceous to Paleocene(?) and Eocene.	Puerto Rico	Pessagno, 1960	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report, p.A33	1967
Montgomery Creek Formation.	Eocene	California	Williams, 1932	Geology of Cascade Range and Modoc Plateau, by G. A. Macdonald.	California Div. Mines and Geology Bull. 190.	1966
New London Gneiss	Ordovician(?) or older	Connecticut	Gregory, 1906	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull. 1224-J	1966
Open Door Limestone Member (of Gallatin Limestone).	Late Cambrian	Wyoming	Shaw and DeLand, 1955.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495-B	1966
Quincy Diatomite Bed (of Priest Rapids Member of Yakima Basalt of Columbia River Group).	late Miocene	Washington	Mackin, 1961	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	1966
Río Descalabrado Formation (of Jacaguas Group).	middle Eocene	Puerto Rico	Hodge, 1920	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report p. A38	1967
Saddle Mountains Member (of Yakima Basalt of Columbia River Group).	late Miocene and early Pliocene.	Washington	Mackin, 1961	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	
Squaw Creek Diatomite Bed (of Frenchman Springs Member of Yakima Basalt of Columbia River Group).	late Miocene	do	do	do	do	1966
Swakane Biotite Gneiss	pre-Tertiary	do	Waters, 1932	Geology of the Glacier Peak quadrangle, Washington, by D. F. Crowder, R. W. Tabor, and A. B. Ford.	Map GQ-473	1966
Vantage Sandstone Member (of Yakima Basalt of Columbia River Group).	late Miocene	do	Mackin, 1961	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	1966

STRATIGRAPHIC NAMES REVISED

Name	Age	Location	Revision	Report in which usage is revised		Year of publication
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Abrams Mica Schist	Carboniferous	California	Restricted to exclude rocks underlying Salmon Hornblende Schist.	Geology of the Klamath Mountains province, by W. P. Irwin.	California Div. Mines and Geology Bull. 190.	1966
Arnheim Formation	Late Ordovician	Kentucky	Arnheim Formation no longer used in Kentucky; Arnheim Shale or Limestone in good usage in other States.	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966
Aspen Formation	Early Cretaceous	Idaho and Wyoming.	Formerly Aspen Shale. Aspen shale in good usage outside report area.	Tectonic development of Idaho-Wyoming thrust belt, by F. C. Armstrong and S. S. Oriel.	Am. Assoc. Petroleum Geologists Bull., v. 49, no. 11.	1965
Avispa Formation (of Río Orocovis Group).	Late Cretaceous	Puerto Rico	Formerly Avispa Lava Member of Río Orocovis Formation.	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244–C	1966
Big Blue Serpentinous Member (of Temblor Formation).	middle Miocene	California	Formerly Big Blue Serpentinous Member of Vaqueros Formation. In good usage as member of Vaqueros Formation outside report area.	Jadeite and asbestos in southern San Benito and western Fresno Counties, California, by R. G. Coleman and W. R. Cohan.	Geol. Soc. America Cordilleran Sec., Guidebook.	1965
Boyle Limestone, Formation, or Dolomite.	Middle Devonian	Kentucky	Boyle Dolomite accepted for use in Berea area.	Pre-Middle Devonian and post-Middle Devonian faulting and the Silurian-Devonian unconformity near Richmond, Kentucky, by G. C. Simmons.	Prof. Paper 550–C	1966
Breathitt Formation	Early and Middle Pennsylvanian.	Tennessee and Kentucky.	Includes Hance, Mingo, Catron, and Hignite Members in eastern Kentucky and adjoining parts of Tennessee northwest of Pine Mountain fault.	Geologic map of the Ketchen quadrangle, Tennessee-Kentucky, by K. J. Englund.	Map GQ–500	1966
Calera Limestone Member (of Franciscan Formation).	Late Cretaceous	California	Formerly Calera Limestone of Franciscan Group. Age formerly Cretaceous and Jurassic.	San Francisco Peninsula, by M. G. Bonilla and Julius Schlocker.	California Div. Mines and Geology Bull. 190.	1966
Cathedral Mountain Formation.	Early Permian (Leonard).	Texas	Includes Wedin Member in in lower part.	New units in the Lower Permian of the Glass Mountains, west Texas, by	Bull. 1244–E	1966

				G. A. Cooper and R. E. Grant.		
Catron Member (of Breathitt Formation).	Middle Pennsylvanian.	Kentucky and Tennessee.	Catron Formation of Breathitt Group reduced in rank to Catron Member of Breathitt Formation in eastern Kentucky and adjoining parts of Tennessee northwest of Pine Mountain fault. Catron Formation in good standing elsewhere.	Geologic map of the Ketchen quadrangle, Tennessee-Kentucky, by K. J. Englund.	Map GQ-500	1966
Chediski Sandstone Member (of Troy Quartzite).	late Precambrian	Arizona	Formerly Chediski White Sandstone Member of Troy Quartzite of Middle Cambrian age.	Geologic map of the Chediski Peak quadrangle, Arizona, by T. L. Finnell.	Map GQ-544	1966
Cuevas Limestone (of Jacaguas Group).	early(?) to middle(?) Eocene.	Puerto Rico	Assigned to Jacaguas Group and age changed from Tertiary(?) to early(?) to middle(?) Eocene.	The Jacaguas Group in central-southern Puerto Rico, by Lynn Glover III and P. H. Mattson.	This report, p. A37	1967
Death Canyon Limestone Member (of Gros Ventre Formation).	Middle Cambrian	Wyoming	Limestone added to name in report area.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495-B	1966
Drakes Formation	Late Ordovician	Kentucky	Upper part includes Saluda Dolomite Member in north-central Kentucky.	Geologic map of the New Haven quadrangle, Nelson and Larue Counties, Kentucky, by W. L. Peterson.	Map GQ-506	1966
Frenchman Springs Member (of Yakima Basalt of Columbia River Group).	late Miocene	Washington	Assigned to Columbia River Group. Formerly considered of late Miocene and early Pliocene age.	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	1966
Gallatin Limestone	Late Cambrian	Wyoming	New members recognized—Du Noir Limestone Member at base and Open Door Limestone Member at top.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495-B	1966
Gerome Volcanics	Oligocene	Washington	Formerly Gerome Andesite	Geologic map of the Wilmont Creek quadrangle, Ferry and Stevens Counties, Washington, by G. E. Becraft.	Map GQ-538	1966
Gros Ventre Formation	Middle Cambrian	Wyoming	Includes following members (ascending order): Wolsey Shale Member, Death Canyon Limestone Member, and Park Shale Member.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495-B	1966

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Hance Member (of Breathitt Formation).	Early and Middle Pennsylvanian.	Kentucky and Tennessee.	Hance Formation of Breathitt Group reduced in rank to Hance Member of Breathitt Formation in eastern Kentucky and adjoining parts of Tennessee northwest of Pine Mountain fault; age changed to Early and Middle Pennsylvanian in this area. Hance Formation of Middle Pennsylvanian age in good standing elsewhere.	Geologic map of the Ketchen quadrangle, Tennessee-Kentucky, by K. J. Englund.	Map GQ–500	1966
Hess Formation	Early Permian (Wolfcamp and Leonard).	Texas	Includes beds of Wolfcamp age formerly assigned to upper part of Lenox Hills Formation of Ross (1959); previously restricted to Leonard Series only.	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Hignite Member (of Breathitt Formation).	Middle Pennsylvanian.	Kentucky and Tennessee.	Hignite Formation of Breathitt Group reduced in rank to Hignite Member of Breathitt Formation in eastern Kentucky and adjoining parts of Tennessee northwest of Pine Mountain fault. Hignite Formation in good standing elsewhere.	Geologic map of the Ketchen quadrangle, Tennessee-Kentucky, by K. J. Englund.	Map GQ–500	1966
Hope Valley Alaskite Gneiss (of Sterling Plutonic Group).	pre-Pennsylvanian	Rhode Island and Connecticut.	Placed in Sterling Plutonic Group.	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull. 1224–J	1966
Kirtland Shale	Late Cretaceous	New Mexico	Redefined to include Naashoibito Member.	History of nomenclature and stratigraphy of rocks adjacent to the Cretaceous-Tertiary boundary, western San Juan basin, New Mexico, by E. H. Baltz, S. R. Ash, and R. Y. Anderson.	Prof. Paper 524–D	1966

Leonard Series	Early Permian	Texas and New Mexico.	Raised everywhere to Series; Leonard Formation replaced in type area by Hess Formation (upper part), and Skinner Ranch, Cathedral Mountain, and Road Canyon Formations.	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Copper and R. E. Grant.	Bull. 1244-E	1966
Martin Formation	Early or Middle to Late Devonian.	Arizona	Divided into Beckers Butte Member of Early or Middle Devonian age at base and Jerome Member of Late Devonian age at top in central Arizona.	Devonian rocks and paleogeography of central Arizona, by Curt Teichert.	Prof. Paper 464	1965
Mingo Member (of Breathitt Formation.	Middle Pennsylvanian.	Kentucky and Tennessee.	Mingo Formation of Breathitt Group reduced in rank to Mingo Member of Breathitt Formation in eastern Kentucky and adjoining parts of Tennessee northwest of Pine Mountain fault. Mingo Formation in good standing elsewhere.	Geologic map of the Ketchen quadrangle, Tennessee-Kentucky, by K. J. Englund.	Map GQ-500	1966
Ojo Alamo Sandstone	Paleocene	New Mexico	Restricted to upper conglomerate of Ojo Alamo Sandstone of Reeside (1924) at Ojo Alamo Arroyo; age changed from Late Cretaceous to Paleocene.	History of nomenclature and stratigraphy of rocks adjacent to the Cretaceous-Tertiary boundary, western San Juan Basin, New Mexico, by E. H. Baltz, S. R. Ash, and R. Y. Anderson.	Prof. Paper 524-D	1966
Park Shale Member (of Gros Ventre Formation).	Middle Cambrian	Wyoming	Park Shale reduced to member rank in Wind River Basin. Park Shale or Park Argillite in good usage elsewhere.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495-B	1966
Perchas Formation (of Río Orocovis Group).	Early(?) and Late Cretaceous.	Puerto Rico	Formerly Perchas Lava Member of Late Cretaceous age of Río Orocovis Formation.	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244-C	1966
Pozas Formation	Late Cretaceous	do	Flor de Alba Limestone Lentil adopted and included in Pozas Formation.	Geology of the Florida quadrangle, Puerto Rico, by A. E. Nelson and W. H. Monroe.	Bull. 1221-C	1966
Priest Rapids Member (of Yakima Basalt of Columbia River Group.	late Miocene	Washington	Assigned to Columbia River Group and age changed from late Miocene or early Pliocene to late Miocene.	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	1966
Queen City Sand (of Claiborne Group).	middle Eocene	Texas	Formerly Queen City Sand Member of Mount Selman Formation.	Ground-water resources of Gonzales County, Texas, by G. H. Shafer.	Texas Water Devel. Board Rept. 4.	1965
Reklaw Formation (of Claiborne Group).	do	do	Formerly Reklaw Member of Mount Selman Formation.	do	do	1965

STRATIGRAPHIC NAMES REVISED—Continued

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Richmond Group	Late Ordovician	Kentucky	Richmond Group no longer used in Kentucky.	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966
Río Orocovis Group	Early and Late Cretaceous.	Puerto Rico	Formerly Río Orocovis Formation of Late Cretaceous age.	Cretaceous and Tertiary rocks in the Corozal quadrangle, northern Puerto Rico, by A. E. Nelson.	Bull. 1244–C	1966
Road Canyon Formation	Early Permian (Leonard).	Texas	Formerly Road Canyon Member of Word Formation, of Early and Late Permian (Guadalupe) age.	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Saluda Dolomite Member (of Drakes Formation).	Late Ordovician	Kentucky	Formerly Saluda Limestone in north-central Kentucky.	Geologic map of the New Haven quadrangle, Nelson and Larue Counties, Kentucky, by W. L. Peterson.	Map GQ–506	1966
Scituate Granite Gneiss (of Sterling Plutonic Group).	pre-Pennsylvanian	Rhode Island and Connecticut.	Placed in Sterling Plutonic Group.	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull.1224–J	1966
Skinner Ranch Formation	Early Permian (Leonard).	Texas	Includes Dugout Mountain Member.	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1244–E	1966
Sterling Plutonic Group	pre-Pennsylvanian	Connecticut and Massachusetts.	Replaces Sterling Granite Gneiss of former usage. Includes Hope Valley Alaskite Gneiss, Scituate Granite Gneiss, and Ten Rod Granite Gneiss.	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull. 1244–J	1966
Swift Sandstone	Late Jurassic	Montana	Swift Sandstone accepted in report area; Swift Formation in good usage elsewhere.	Structural framework of north part of Barker quadrangle, Little Belt Mountains, Montana, by I. J. Witkind.	Geol. Soc. America Spec. Paper 87.	1966
Ten Rod Granite Gneiss (of Sterling Plutonic Group).	pre-Pennsylvanian	Rhode Island and Connecticut.	Placed in Sterling Plutonic Group.	Stratigraphic names in the New London area, Connecticut, by Richard Goldsmith.	Bull. 1224–J	1966

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Trimmers Rock Formation (of Susquehanna Group).	Late Devonian	Pennsylvania	Formerly Trimmers Rock Sandstone, which is in good usage outside report area.	Geology of the Ransom quadrangle, Lackawanna, Luzerne, and Wyoming Counties, Pennsylania, by T. M. Kehn, E. E. Glick, and W. C. Culbertson.	Bull. 1213	1966
Tyee Formation	middle Eocene	Oregon	Strata previously assigned to Burpee Formation are relegated to Tyee Formation.	Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range, by P. D. Snavely, Jr., H. C. Wagner, and N. S. Macleod.	Kansas Geol. Survey Bull. 169.	1964 [1966]
Waynesville Shale	Late Ordovician	Kentucky	Waynesville Limestone no longer used in Kentucky. Waynesville Shale in good usage in Ohio.	Revised nomenclature of Upper Ordovician formations in the Maysville, Kentucky, area, by J. H. Peck.	Bull. 1244–B	1966
Weches Greensand (of Claiborne Group).	middle Eocene	Texas	Formerly Weches Greensand Member of Mount Selman Formation.	Ground water resources of Gonzales County, Texas, by G. H. Shafer.	Texas Water Devel. Board Rept. 4.	1965
Wolsey Shale Member (of Gros Ventre Formation).	Middle Cambrian	Wyoming	Reduced to member rank in Wind River Basin. Wolsey Shale or Formation in good usage elsewhere.	Paleozoic formations in the Wind River basin, Wyoming, by W. R. Keefer and J. A. Van Lieu.	Prof. Paper 495–B	1966
Word Formation	Early and Late Permian (Guadalupe).	Texas	Road Canyon Member raised to formation and removed from Word Formation, which includes following new members: China Tank, Willis Ranch, and Apple Ranch Members.	New units in the Lower Permian of the Glass Mountains, west Texas, by G. A. Cooper and R. E. Grant.	Bull. 1224–E	1966
Yakima Basalt	late Miocene and early Pliocene.	Washington	Upper part of Yakima Basalt locally subdivided into (ascending order) Frenchman Springs, Roza, and Priest Rapids Members.	*Stratigraphy of the upper* part of the Yakima Basalt in Whitman and eastern Franklin Counties, Washington, by J. W. Bingham and K. L. Walters.	Prof. Paper 525–C	1965
Yakima Basalt (of Columbia River Group).	do	do	Included in Columbia River Group. Locally subdivided into (ascending order) lower basalt flows, Vantage Sandstone Member, and Frenchman Springs, Roza, Priest Rapids, and Saddle Mountains Members.	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham, and M. J. Grolier.	Bull. 1224–G	1966

CHANGES IN AGE DESIGNATION

Name	Age		Location	Report in which age designation is changed		Year of publication
	New	Former		Title and authorship	Publication (U.S. Geol. Survey except as indicated)	
Allegheny Formation	Middle and Late Pennsylvanian.	Middle Pennsylvanian.	Pennsylvania	Geology of the Ransom quadrangle, Lackawanna, Luzerne, and Wyoming Counties, Pennsylvania, by T. M. Kehn, E. E. Glick, and W. C. Culbertson.	Bull. 1213	1966
Baird Formation	Mississippian and Early Pennsylvanian.	Mississippian	California	Geology of the Klamath Mountains province, by W. P. Irwin.	California Div. Mines and Geology Bull. 190.	1966
Birch Creek Schist	Precambrian or early Paleozoic.	Precambrian	Alaska	Geologic map of the Fairbanks quadrangle, Alaska, by T. L. Péwé, Clyde Wahrhaftig, and F. R. Weber.	Map I-455	1966
Butano Sandstone	Eocene	Oligocene or Eocene	California	Geology of the Palo Alto quandrangle, Santa Clara and San Mateo Counties, California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Map Sheet 8.	1966
Chickaloon Formation	Paleocene	Paleocene(?) and Eocene.	Alaska	Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska, by J. A. Wolfe, D. M. Hopkins, and E. B. Leopold.	Prof. Paper 398-A	1966
Dalles Formation	early and middle(?) Pliocene.	Pliocene	Oregon and Washington.	Lithology and eastward extension of the Dalles Formation, Oregon and Washington, by R. C. Newcomb.	Prof. Paper 550-D	1966
Dalton Formation	Early Cambrian(?)	Early Cambrian	Massachusetts	Geologic map of the Bashbish Falls quadrangle, Massachusetts, Connecticut, and New York, by E-an Zen and J. H. Hartshorn.	Map GQ-507	1966
Fairbanks Loess	Pleistocene	Quaternary	Alaska	Geologic map of the Fairbanks quadrangle, Alaska, by T. L. Péwé, Clyde Wahrhaftig, and F. R. Weber.	Map I-455	1966
Fina-sisu Formation	early Miocene	late Oligocene	Saipan	Smaller Foraminifera from Guam, by Ruth Todd.	Prof. Paper 403-I	1966
Gazelle Formation	Early(?), Middle and Late(?) Silurian.	Middle Silurian to Early Devonian.	California	Geology of the Klamath Mountains province, by W. P. Irwin.	California Div. Mines and Geology Bull. 190.	1966
Horse Spring Formation.	Miocene(?)	Eocene(?)	Nevada	The geology and mineral deposits of Clark County, Nevada, by C. R. Longwell, E. H. Pampeyan, B. Bower and B. J. Roberts.	Nevada Bur. Mines Bull. 62.	1966
Janum Formation	Miocene and Pliocene.	late Miocene and Pliocene.	Guam	Smaller Foraminifera from Guam, by by Ruth Todd.	Prof. Paper 403-I	1966

Kenai Formation	late Oligocene(?), Miocene, and Pliocene.	Eocene(?) and Oligocene.	Alaska	Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska, by J.A. Wolfe, D. M. Hopkins, and E.B. Leopold.	Prof. Paper 398–A	1966
Kotsina Conglomerate	Middle or Late Jurassic.	Jurassic	do	Stratigraphy, paleontology and isotopic ages of upper Mesozoic rocks in the southwestern Wrangell Mountains, Alaska, by Arthur Grantz, D. L. Jones, M. A. Lanphere.	Prof. Paper 550–C	1966
Nenana Gravel	Pliocene(?)	middle Miocene or younger.	do	Geologic map of the Fairbanks quadrangle, by T. L. Péwé, Clyde Wahrhaftig, and F. R. Weber.	Map I–455	1966
New Albany Shale	late Middle and Late Devonian and Early Mississippian.	Late Devonian	Kentucky (along the east flank of the Cincinnati Arch north of Lat 37°15′).	Pre-Middle Devonian and post-Middle Devonian faulting and the Silurian-Devonian unconformity near Richmond, Kentucky, by G. C. Simmons.	Prof. Paper 550–C	1966
Nilkoka Group	Precambrian or Paleozoic.	Precambrian	Alaska	Geologic map of the Fairbanks quadrangle, by T. L. Péwé, Clyde Wahrhaftig, and F. R. Weber.	Map I–455	1966
Priest Rapids Member (of Yakima Basalt of Columbia River Group).	late Miocene	late Miocene or early Pliocene.	Washington	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224–G	1966
Purisima Formation	early and middle Pliocene.	Pliocene	California	Evidence for cumulative offset on the San Andreas fault in central and northern California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Bull. 190.	1966
Rattlesnake Formation.	middle Pliocene and Pleistocene(?).	Pliocene and Pleistocene.	Oregon	Geologic map of the Aldrich Mountain quadrangle, Grant County, Oregon, by T. P. Thayer and C. E. Brown.	Map GQ–438	1966
Rest Spring Shale	Late Mississippian	Late Mississippian and Pennsylvanian(?).	California	Stratigraphy of some Paleozoic formations in the Independence quadrangle, Inyo County, California, by D. C. Ross.	Prof. Paper 396	1966
San Lorenzo Formation.	Eocene and Oligocene.	Oligocene	do	Geology of the Palo Alto quadrangle, Santa Clara and San Mateo Counties, California, by T. W. Dibblee, Jr.	California Div. Mines and Geology Map Sheet 8.	1966
Sentinel Granodiorite.	Late Cretaceous	Cretaceous	do	Potassium-argon ages of coexisting minerals from pyroxene-bearing granitic rocks in the Sierra Nevada, California, by R. W. Kistler and F. C. W. Dodge.	Jour. Geophys. Research, v. 71, no. 8.	1966
Sunday Canyon Formation.	Silurian and Devonian(?).	Silurian	do	Stratigraphy of some Paleozoic formations in the Independence quadrangle, California, by D. C. Ross.	Prof. Paper 396	1966
Tehama Formation	late Pliocene	Pliocene	do	Geology of Cascade Range and Modoc Plateau, by G. A. Macdonald.	California Div. Mines and Geology Bull. 190.	1966
Tepee Trail Formation	middle and late Eocene.	late Eocene	Wyoming	Geologic map of the Kissinger Lakes quadrangle, Fremont County, Wyoming, by W. L. Rohrer.	Map GQ–527	1966

CHANGES IN AGE DESIGNATION—Continued

Name	Age		Location	Report in which age designation is changed		Year of publication
	New	Former		Title and authorship	Publication (U.S. Geol. Survey except as indicated)	
Tolovana Limestone	Middle Silurian to Middle or Late Devonian.	Middle Silurian	Alaska	Geologic map of the Fairbanks quadrangle, by T. L. Péwé, Clyde Wahrhaftig, and F. R. Weber.	Map I-455	1966
Tsadaka Formation	early to middle Miocene.	Eocene(?) and Oligocene.	do	Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska, by J. A. Wolfe, D. M. Hopkins, and E. B. Leopold.	Prof. Paper 398-A	1966
Umpqua Formation	early to middle Eocene.	early Eocene	Oregon	Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range, by P. D. Snavely, Jr., H. C. Wagner, and N. S. MacLeod.	Kansas Geol. Survey Bull. 169.	1964 [1966]
Valdez Group	Jurassic(?) and Cretaceous.	Jurassic or Cretaceous.	Alaska	Gravity survey and regional geology of Prince William Sound epicentral region, Alaska by J. E. Case, D. F. Barnes, George Plafker, and S. L. Robbins.	Prof. Paper 543-C	1966
Vaughn Gulch Limestone.	Silurian and Devonian(?).	Silurian	California	Stratigraphy of some Paleozoic formations in the Independence quadrangle, California, by D. C. Ross.	Prof. Paper 396	1966
Wishbone Formation	Paleocene(?) and Eocene(?).	Eocene	Alaska	Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska, by J. A. Wolfe, D. M. Hopkins, and E. B. Leopold.	Prof. Paper 398-A	1966

STRATIGRAPHIC NAMES REINSTATED

Name	Age	Location	Report in which name is reinstated: Title and authorship	Report in which name is reinstated: Publication (U.S. Geol. Survey except as indicated)	Year of publication
Harrodsburg Limestone	Early and Late Mississippian.	Indiana and Kentucky.	Geologic map of the New Haven quadrangle, Nelson and Larue Counties, Kentucky, by W. L. Peterson.	Map GQ-506	1966

STRATIGRAPHIC NAMES ABANDONED

Name	Age	Location	Report in which name is abandoned: Title and authorship	Report in which name is abandoned: Publication (U.S. Geol. Survey except as indicated)	Year of publication
Burpee Formation	middle Eocene	Oregon	Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range, by P. D. Snavely, Jr., H. C. Wagner, and N. S. MacLeod.	Kansas Geol. Survey Bull. 169.	1964 [1966]
Wenas Basalt Member (of Yakima Basalt of Columbia River Group).	early Pliocene	Washington	The Yakima Basalt and Ellensburg Formation of south-central Washington, by J. W. Bingham and M. J. Grolier.	Bull. 1224-G	1966

CUYÓN FORMATION OF EAST-CENTRAL PUERTO RICO

By Lynn Glover III

Prepared in cooperation with The Commonwealth of Puerto Rico Economic Development Administration, Industrial Research Department

The Cuyón Formation is herein named for outcrops along Puerto Rico Highway 162 just south of the headwaters of the Río Cuyón in northwestern Cayey quadrangle (fig. 1). These rocks were previously included in the Robles Formation by Berryhill and Glover (1960).

The formation is heterogeneous and consists of about 75 m of rocks divided into three subequal parts. The basal third is reddish- to

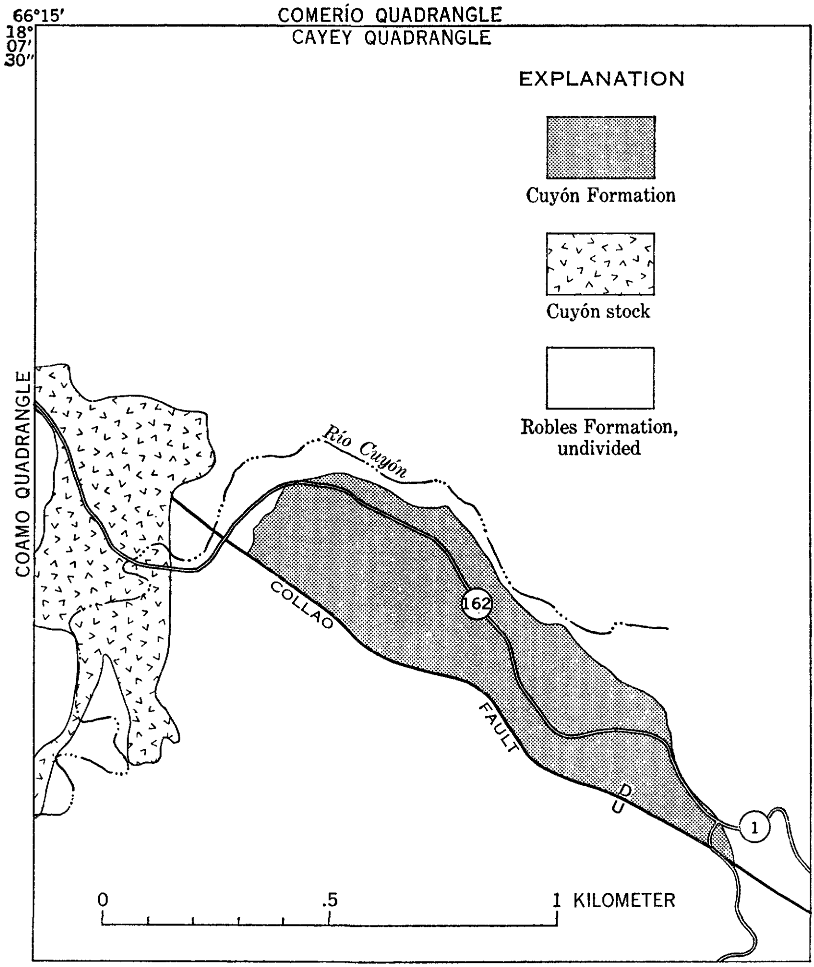


FIGURE 1. Distribution of the Cuyón Formation in the northwest corner of the Cayey 7½-minute quadrangle, east-central Puerto Rico.

purplish-gray poorly sorted volcaniclastic sandstone that is obscurely stratified in thin to medium-thick beds. The middle third is composed of drab thin- to thick-bedded reworked tuff with lenses of volcaniclastic conglomerate. The upper part of the Cuyón is an unnamed member of hard bluish-gray fossiliferous limestone in thin to medium-thick beds interleaved with volcaniclastic sandstone. Contact metamorphism in the vicinity of the Cuyón stock has converted the limestone to skarn.

The base of the formation appears to rest unconformably upon thin-bedded tuff and massive conglomerate of the Albian to Santonian Robles Formation. No upper sedimentary contact is known; younger rocks if present were cut out by the Collao fault or eroded away.

Macrofossils collected from the limestone member suggest a Late Cretaceous (Campanian to Maestrichtian) age according to N. F. Sohl (written commun., 1957, 1959, 1960, 1965). Microfossils collected from the same locality suggest a late Maestrichtian age according to E. A. Pessagno (written commun., 1965).

The Cuyón is correlative, at least in part, with the Miramar Formation (Glover and Mattson, 1960; this report, p. A33) of central southern Puerto Rico and the San German Formation of Mattson (1960) of southwestern Puerto Rico.

THE MATILDE AND MILAGROS FORMATIONS OF EARLY TERTIARY AGE IN NORTHWEST PUERTO RICO

By Arthur E. Nelson and Othmar T. Tobish

Prepared in cooperation with The Commonwealth of Puerto Rico Economic Development Administration, Industrial Research Department

Two newly defined formations of lower Tertiary volcanogenic rocks have been mapped by the authors in the Bayaney quadrangle, northwest Puerto Rico (fig. 2). The older (Matilde Formation) consists mostly of thin-bedded volcanic sandstone and siltstone; the younger (Milagros Formation) is mostly a mixture of lapilli tuff and volcanic breccia.

MATILDE FORMATION

A sequence of thin-bedded [1] volcanic sandstone and siltstone with some intercalated andesite flows and deposits of lapilli tuff is here named the Matilde Formation after the settlement of Matilde. The type section, about half a kilometer northwest of Matilde, consists of exposures along a dirt road in the Bayaney quadrangle between (48,680 N., 108,520 E. and 48,780 N., 108,660 E., Puerto rectangular coordinate system, in meters).

[1] In this report, beddings of thicknesses less than 5 cm, 5-50 cm, and more than 100 cm, are referred to as thin, medium, or massive, respectively.

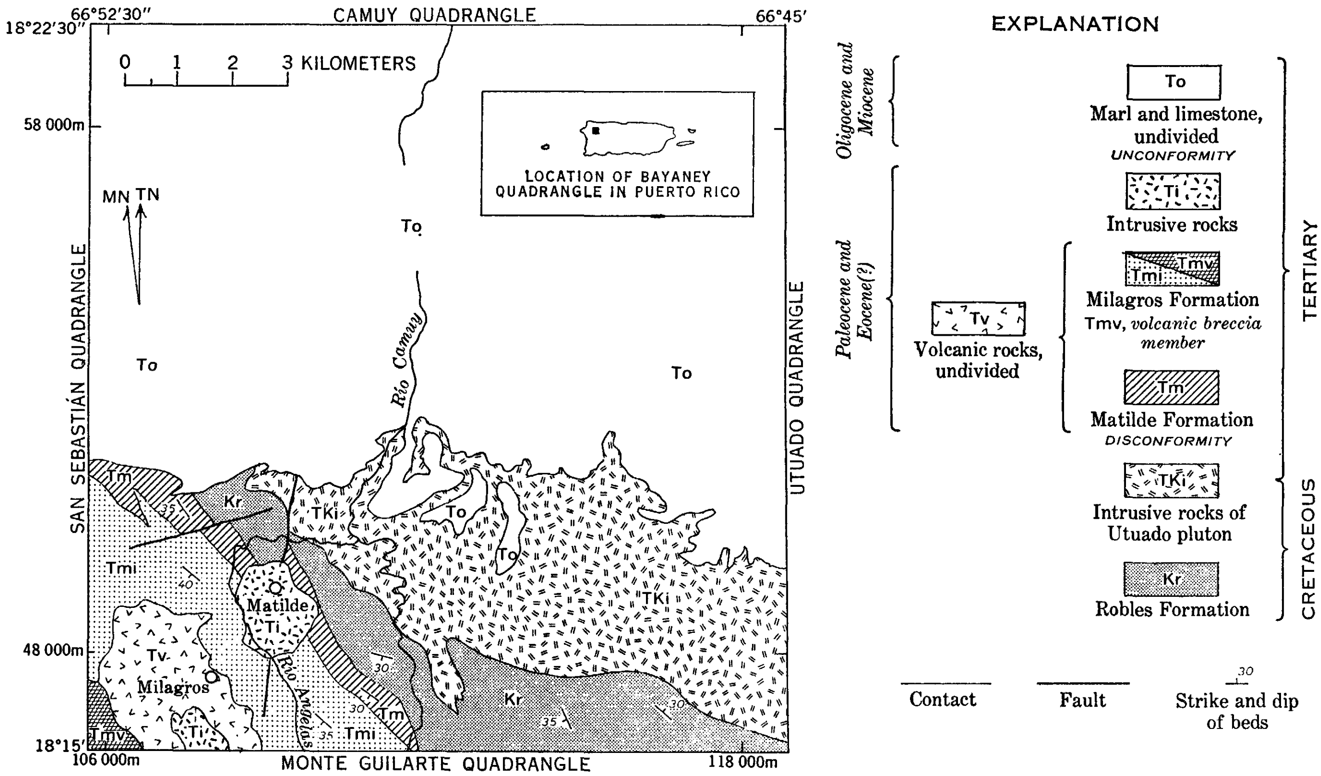


FIGURE 2.—Geologic sketch map of the Bayaney quadrangle, Puerto Rico.

The Matilde Formation ranges in thickness from 115 to 620 m and trends northwest across the southwest part of the quadrangle. The formation is on the south limb of the principle fold of the west- to northwest-trending island anticlinorium, and, except for complications due to local folding, most of the strata dip to the southwest.

Most of the Matilde is pale-green to pale-blue fine-grained tuff and grayish-brown fine- to medium-grained volcanic sandstone and siltstone. Minor amounts of volcanic breccia and some flows of andesite lava are also present. With the exception of massively bedded volcanic breccia and andesite lavas, the strata are chiefly thin to medium bedded.

Some of the tuffs, which range from crystal vitric to vitric, are well sorted and layered and thus are presumed to be airborne water-laid deposits. They consist mostly of plagioclase crystals and fragments together with some rock fragments embedded in a matrix rich in pale-green material, presumably partly devitrified volcanic glass. In places the tuffs contain a high percentage of shards, most of which are not deformed. Locally, a distinctive pale-bluish-green mineral, probably celadonite, is present, and some beds contain quartz grains.

Interbedded units of lava are medium-gray fine-grained andesite that contains sparse phenocrysts of plagioclase (An_{54-62}) in a very fine textured groundmass with intersertal texture, Although some clinopyroxene is present, it is not common.

Volcanic breccia, which is massively bedded, contains feldspathic (andesitic?) lava fragments in a crystalline matrix rich in plagioclase, some clinopyroxene, and chlorite.

The Matilde Formation rests disconformably upon the underlying Robles Formation (Pease and Briggs, 1960) of Early to Late Cretaceous age. The lower contact of the Matilde is placed at the base of the volcanic sandstone that rests upon pyroxene-rich volcanic breccia and lapilli tuff of the Robles. The upper contact is placed at the top of the uppermost thin-bedded volcanic sandstone underlying massive lapilli tuff of the Milagros Formation.

Fossils occurring in the Matilde indicate it is early Tertiary (late Paleocene and Eocene) in age (E. A. Pessagno, written commun., 1965). Pessagno identified *Globigerina* sp., rare *Globorotalia* s.s. sp. (keeled forms), *Stylospongia* s.s. sp., and other spumellinid radiolaria in samples collected from the formation. The Matilde probably is equivalent in age to the Yunes Formation in the Florida and Utuado quadrangles (Nelson and Monroe, 1966; Nelson, 1967), but in critical areas their mutual relationships are unknown because they are concealed by unconformably overlying middle Tertiary deposits. Both the Matilde and Yunes occupy nearly equivalent stratigraphic positions, and both are similar in lithology. To the southeast in the

Adjuntas quadrangle, the Río Prieto, Monserrate, and Anón Formations range from early to middle (and possibly late) Eocene age (Mattson, 1967, 1967a). The Matilde has not been laterally traced into any of these units because intervening areas have not been mapped, but a tentative correlation of the Matilde with all or parts of the Río Prieto and (or) Monserrate Formations seems reasonable.

MILAGROS FORMATION

Massive deposits of feldspathic lapilli tuff interstratified with some volcanic breccia, andesitic lave flows, and thin-bedded volcanic sandstone and siltstone are here named the Milagros Formation after the settlement of Milagros. Exposures along the Río Angeles about 1½ km east-southeast of Milagros between coordinate lines 46,740 and 46,240 constitute the type section.

The Milagros, which occupies much of the southwest corner of the quadrangle, parallels the trend of the Matilde Formation; it is at least 1,700 m thick in the Bayaney quadrangle.

Most of the Milagros consists of medium-gray feldspathic lapilli tuff and dark-brownish-gray volcanic breccia; included are some units of andesite lava and interbeds of vitric and crystal tuff, volcanic sandstone and siltstone. Both the lapilli tuff and volcanic breccia principally consist of andesitic lava fragments in a crystalline matrix rich in plagioclase, some clinopyroxene, chlorite, and minor quartz. The andesite units are fine grained and bluish gray and contain plagioclase phenocrysts. Interbeds of tuff and volcanic sandstone and siltstone are generally fine grained and thin bedded and range from pale green to brownish gray. Celadonite(?) imparts a green color to the formation in places.

A distinctive volcanic breccia unit containing some interbeds of andesite lava crops out in the southwest corner of the Bayaney quadrangle. On the geologic map this is shown separately as an unnamed member of the Milagros, but its lower contact with the rest of the Milagros is obscured by hydrothermal alteration, and its upper part is not exposed in the Bayaney quadrangle. About 500 m of the volcanic breccia member is exposed in the Bayaney quadrangle.

The volcanic breccia, which is massively bedded, consists primarily of angular to subrounded fragments of andesite lava. These fragments are reddish-brown feldspathic (andesitic) lava fragments that commonly contain numerous plagioclase phenocrysts in a finely crystalline groundmass. The matrix of the breccia is rich in fragments and crystals of plagioclase, some clinopyroxene, oxidized pumice, and, locally, quartz.

The Milagros rests conformably upon the Matilde Formation, and the contact is known to be a distinctive break, although at most places the contact zone is concealed by vegetation and deep saprolite. The upper contact of the Milagros is not exposed in the Bayaney quadrangle.

Fossils have not been found in the Milagros Formation, but it overlies the Matilde Formation of Paleocene and Eocene age and is probably Eocene in age. The Milagros may be equivalent in age to part of the Jobos Formation (Nelson and Monroe, 1966), as the Milagros is quite similar in lithology and occupies a stratigraphic position nearly equivalent to that of the Jobos. It is also possible that the Milagros is equivalent in age to parts of the Río Prieto, Monserrate, and Anón Formations exposed in the Adjuntas quadrangle, as these later formations range from early to middle and possibly late Eocene in age (Mattson, 1967a).

THE MALO BRECCIA AND COTORRA TUFF IN THE CRETACEOUS OF CENTRAL PUERTO RICO

By REGINALD P. BRIGGS

Prepared in cooperation with The Commonwealth of Puerto Rico Economic Development Administration, Industrial Research Department

The Malo Breccia and Cotorra Tuff, herein named and described, are massive volcanic units stratigraphically equivalent to the middle and upper Robles Formation (Pease and Briggs, 1960). The Robles is composed chiefly of thin-bedded volcanic sandstone and siltstone and is Cretaceous (Albian to Santonian) in age (Douglass, 1961; Kauffman, 1964). The chief occurrences of the Malo and Cotorra are in the Orocovis 7½-minute quadrangle, central Puerto Rico, whereas the greatest thickness of the Robles Formation (2,100 m) is in the Barranquitas quadrangle, which adjoins the Orocovis quadrangle on the east (Briggs and Gelabert, 1962).

The hydrogeologic map of Puerto Rico (Briggs and Akers, 1965) provides the regional geologic setting. On this map the Orocovis quadrangle may be located by the towns of Orocovis and Villalba, which are in the northeastern and southwestern corners of the quadrangle, respectively.

MALO BRECCIA

The Malo Breccia is here named for Cerro El Malo, a peak on the Cordillera Central in the southeast-central part of the Orocovis quadrangle. The type locality (37,830 N.; 153,830 E., Puerto Rico rectangular coordinate system, in meters) is on a foot trail along the east flank of Cerro El Malo. Here relatively fresh pyroclastic breccia (Fisher, 1961), typical of a large part of the Malo, is exposed. The average breccia block is about 15 cm in diameter, but blocks 80 cm in longest dimension occur. Most are buff, dark-reddish-brown, dark-gray, and bluish-gray porphyritic lava, with fine feldspar phenocrysts.

Some blocks also contain clinopyroxene phenocrysts, locally to the exclusion of feldspar phenocrysts. Most blocks probably are andesitic in composition but some may be basaltic. Quartz seems to be absent in the Malo. In some outcrops, large fragments of volcanic sandstone as large as 1 m across are found. In exposures in the lower part of the formation, dark-reddish-brown lava blocks (possibly fragmented bombs) commonly predominate, as is well illustrated in roadcuts on Highway 143 (36,960 N.; 155,910 E.), about 4 km east of the type locality.

The matrix of the breccia is gray to bluish gray where fresh, and is composed chiefly of feldspar crystals and crystal fragments, mostly in the very coarse and coarse sand size ranges. Crystals of clinopyroxene also are common, chiefly in the upper part of the Malo, and lithic fragments of lapilli size and smaller are seen frequently. For the most part, blocks are closely packed in this crystal-rich matrix, but in the lower part of the Malo are massive strata where blocks are small, sparse, or absent, and the rock may be described as a crystal or crystal-lithic tuff. Where blocks are tightly packed, they are generally subround to subangular in shape. However, where packing is less dense and the blocks "float" free in the tuff matrix, they are more commonly angular to subangular. In most outcrops, blocks and matrix show no evidence of interaction. Locally, in the upper part of the formation, however, alteration of block rims and adjacent matrix may be seen. This feature is well exposed on Highway 151 (37,440 N.; 151,050 E.), about 3 km west-southwest of the type locality.

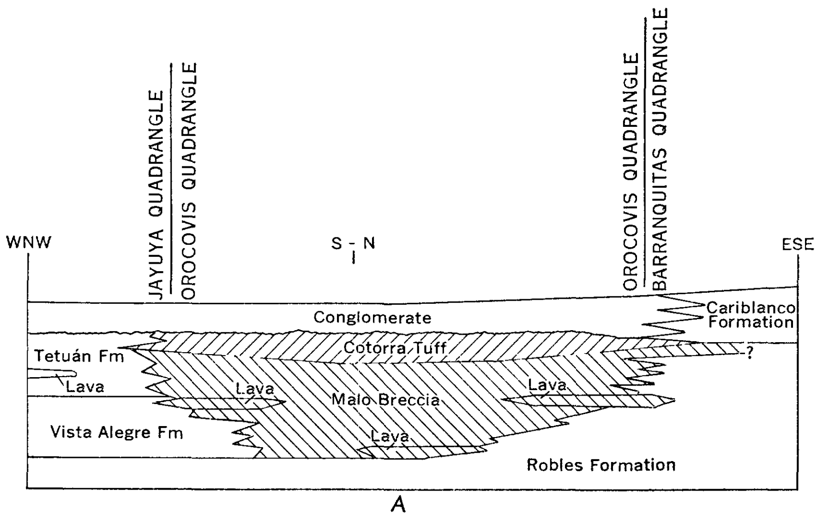
The breccia is massive in character; individual strata or lenses within the formation may exceed 200 m in thickness, but for the most part thicknesses are measured in tens of meters.

Lenses of andesitic lava with moderate to abundant feldspar phenocrysts occur locally at the base and in the middle part of the Malo and are as much as 100 m thick. Pillow structure is well formed in some of these lenses, and pillows were found "floating" in a typical Malo matrix above one lava lens. Thin-bedded volcanic sandstone also occurs interstratified with the breccia, at places in units 50 m thick. The volcanic sandstone occurrences are most common east of the type locality. This fact provides evidence for the facies change from breccia to finer volcaniclastic rocks of the Robles Formation.

Zeolitization is widespread, chlorite and pyrite are common, and locally epidote is present.

The Malo Breccia is believed to be thickest, at least 1,300 m, in the area 2 km west of Cerro El Malo, but the maximum thickness is not known, for the base is not exposed here. The great thickness in this area and the block-matrix interactions referred to above suggest that this was the volcanic center of the Malo accumulation. However, no true vent agglomerates were recognized here or elsewhere. The Malo is considerably thinner only a few kilometers east and west of this area. To the east, the Malo interfingers with the Robles Formation and ultimately pinches out between the Robles and the overlying Cariblanco Formation in the Barranquitas quadrangle (Fig. 3, *A*). The geologic map of the Barranquitas quadrangle (Briggs and Gelabert, 1962) shows no Malo Breccia, however, for at the time of mapping, Briggs and Gelabert did not recognize it as a separate unit; they included it in the base of the Cariblanco.

To the west, in the Jayuya quadrangle (Mattson, 1967b), the Malo also apparently interfingers and pinches out. The belt of outcrop of the Malo Breccia is relatively narrow and trends westerly to northwesterly. The Malo is eroded to the north and covered to the



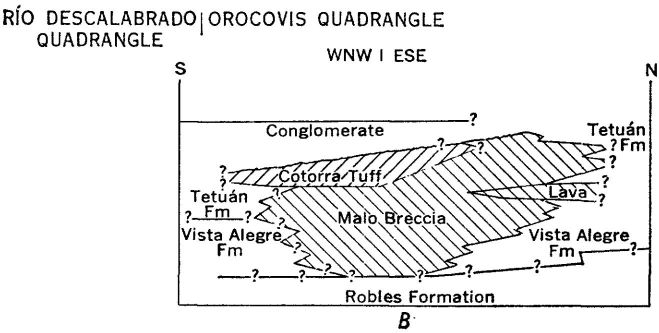


FIGURE 3.—Schematic diagrams showing relations of the Malo Breccia, the Cotorra Tuff, and adjacent stratigraphic units.

south, so its extent and thickness variations in these directions are not known.

The Malo Breccia is a lateral equivalent of the middle and upper parts of the Robles Formation and to the west, and perhaps to the north and south, it interfingers with or grades into the tuff and volcanic sandstone of the Tetuán and Vista Alegre Formations (fig. 3; Mattson, 1967b). Where its base is exposed the Malo rests conformably on Robles strata, except in the vicinity of the border of the Orocovis and Jayuya quadrangles, where it rests on strata assigned to the Vista Alegre. In most of its outcrop area the Malo Breccia is overlain by the Cotorra Tuff, but in the easternmost Malo outcrops it is overlain by the Cariblanco Formation, and in western outcrops it underlies the Tetuán Formation. In the area of thickest breccia accumulation, the top of the Malo has been eroded away. Field and lithologic relationships suggest a possible interfingering of the Cotorra Tuff into the uppermost part of the Malo Breccia about 3 km west-southwest of Cerro El Malo (Fig. 3, *B*). Structural complications and erosion, however, prevent proof of this relationship.

No fossils were found in the Malo Breccia. Because the Malo is stratigraphically equivalent to the middle and upper parts of the Robles Formation farther east, the Malo is probably Late Cretaceous in age; more specifically it may range from the Cenomanian into the Santonian Stage. Despite the lack of marine fossils, which is not surprising in such massive coarse volcanic rocks, the Malo was probably deposited in a marine environment; it is a facies of the marine Robles, and the relatively great lateral extent relative to the thickness of individual massive strata, and the fairly good, if bimodal, sorting in the Malo suggest marine deposition. In addition, the Malo bears pillow lavas and units of well-stratified volcanic sandstone. On the other hand, many Malo blocks are oxidized; they may have been erupted into shallow water or the atmosphere, and there remains the possibility that some of the youngest Malo Breccia, now eroded from the area of thickest accumulation, was deposited subaerially.

The topographic expression of the Malo is distinct. It weathers to red clay and residual boulders. Boulder size is controlled by joint spacing; where joints are very widely spaced and Malo strata are thickest, the Malo forms virtually bare rounded knobs, such as Cerro El Malo, that are similar to South African kopjes. It is generally more resistant than adjacent formations, most notably the Cotorra Tuff, and at many places the Malo Breccia forms sheer cliffs more than 50 m high.

COTORRA TUFF

The Cotorra Tuff is here named for Quebrada La Cotorra, a tributary of the Río Toa Vaca in the southern part of the Orocovis quadrangle. Its type locality is a roadcut on Highway 559 (35,930 N.; 151,660 E.), about 1 km west of Quebrada La Cotorra.

The Cotorra is composed of massive basaltic crystal-vitric tuff and tuff breccia, similar in many respects to the aquagene tuff and related broken-pillow and isolated-pillow breccias described by Carlisle (1963). In the broad terminology of Rittman (1962, p. 72), the Cotorra is a hyaloclastite. At the type locality, the tuff is composed of euhedral clinopyroxene crystals as large as 6 mm across, set in an indeterminate matrix, which is probably chiefly devitrified volcanic glass. Blocks of pyroxene phenocryst basaltic lava from less than 1 cm to 50 cm in longest dimension are well distributed within the tuff at the type locality but probably make up less than 10 percent of the rock. Elsewhere, the tuff contains from 0 to about 50 percent basalt blocks; locally, basaltic pillows about 70 cm in diameter are found isolated within the tuff. The Cotorra ranges in color from dark olive green to bluish black.

At its base and at its top the Cotorra commonly contains bluish-black basaltic pillow lava, and about 5 km east of the type locality, where the Cotorra is thin, the formation is completely composed of basaltic lava. In the area about 0.6 km northeast of the type locality, the lower 20 m of the Cotorra contains blocks similar to those in the Malo Breccia in a typical Cotorra crystal-vitric tuff matrix. In the same general vicinity the Cotorra also contains a few thin beds of fine-grained almost laminated clinopyroxene-crystal tuff. In a western tributary of the Quebrada La Cotorra, a small basaltic sill within the Cotorra Tuff displays columnar jointing (35,940 N.; 152,780 E.). This sill and some basaltic dikes that intrude the lower Cotorra in the valley of the Quebrada La Cotorra suggest that the general type area is also the area in which the tuff was extruded.

The Cotorra ranges from 0 to about 500 m in thickness. In the area from the type locality to about 2 km to the south the Cotorra may be at its thickest. A short distance north of the type locality, however, the Cotorra is very thin; only 1.3 km north-northwest, the unit is about 20 m thick (fig. 3, *A*). It pinches out about 7 km east-southeast of the type area in the southwestern corner of the Barranquitas quadrangle. To the west its extent is unknown because of cover and complicated structure, but it appears to be at least 200 m thick in the southeastern corner of the Jayuya quadrangle (Mattson, 1968b), 8 km west-southwest of the type area. A few kilometers west-northwest of the type area the Cotorra grades into the broadly similar but generally finer grained, more thinly stratified, and less homogeneous Tetuán Formation, and lenses of rock typical of the Cotorra occur within the Tetuán (fig. 3, *B*).

The Cotorra strikes and dips generally parallel to the Malo Breccia. Erosion to the north and cover by younger strata to the south limit knowledge of the extent and thickness of the Cotorra in these directions. However, the abrupt northward thinning of the Cotorra suggests that its northward spread was obstructed by the great volcanic pile that is now the Malo Breccia. This close relationship of the two formations and the fact that the Malo bears appreciable quantities of clinopyroxene in its upper part and that the Cotorra bears typical Malo blocks at least locally in its base, suggest that the upper part of the Malo and the Cotorra may be contemporaneous. However, the Cotorra is faulted off in the critical area, so an intertonguing or gradational relationship could not be proved.

The Cotorra rests on the Malo Breccia in all outcrops except near the border of the Orocovis and Jayuya quadrangles, where it rests on the Tetuán Formation. Throughout most of its outcrop area the Cotorra is overlain conformably by a volcanic conglomerate that is the lateral equivalent of part of the Cariblanco Formation. However, in the area north of the type locality, where the Cotorra is very thin, the relationship is unconformable, and fragments of basaltic pillow lava of the Cotorra occur in the base of the conglomerate.

No fossils were found in the Cotorra Tuff. Nevertheless, it is considered marine in origin because of the presence of pillow lavas and because of its relationship to the Malo volcanic pile and its resemblance to the well-described aquagene tuff of Carlisle (1963). It is correlated in time with the uppermost parts of the Malo Breccia and therefore with the uppermost Robles Formation and thus is Late Cretaceous, perhaps Santonian, in age.

The Cotorra is lithologically similar to the Los Negros Formation described by Nelson (1966) in the Corozal quadrangle to the northeast, and a general correlation of the Cotorra with the upper part of the Los Negros is reasonable on the bases of lithologic comparison and the known regional geology. It is considered best to treat the Cotorra and Los Negros as distinct stratigraphic entities, however, because their closest outcrops are more than 15 km apart, a significant distance in the complex volcanic stratigraphy, and faults with large displacements intervene. Moreover, the Los Negros is appreciably thicker than the Cotorra, perhaps representing a proportionately longer interval of geologic time, and the age of the Los Negros is not closely defined.

The Cotorra weathers to a granular soil and is easily eroded under tropical conditions; in contrast with the Malo Breccia, the Cotorra is a valley former. In the area between the type locality and Quebrada

La Cotorra it underlies an irregular bowl, surrounded to the north and east by highlands underlain by Malo Breccia and to the south and west by highlands underlain by younger units.

HUACHUCA QUARTZ MONZONITE, HUACHUCA MOUNTAINS, COCHISE COUNTY, ARIZONA

By Philip T. Hayes

The Huachuca Quartz Monzonite is here named for extensive exposures in the southern part of the Huachuca Mountains, Cochise County, Ariz., which are designated as its type area (fig. 4). Most of the formation consists of medium- to coarse-grained equigranular rock consisting of roughly equal proportions of pink orthoclase, white plagioclase, and gray quartz. Biotite is the common varietal mineral and hornblende is usually present.

Modal analyses of three specimens of the Huachuca Quartz Monzonite gave the following results, in percent:

	Range	*Average*
Quartz	24. 9–35. 0	29. 2
Orthoclase	16. 4–28. 4	24. 2
Plagiolcase (oligoclase)	31. 2–43. 4	37. 3
Biotite	5. 6–13. 0	8. 1
Hornblende	. 0–. 7	. 3
Magnetite	. 5–1. 6	. 9
Apatite	Tr.	Tr.
Zircon	Tr.	Tr.
Sphene	0–Tr.	Tr.

Most of the bounding contacts of the Huachuca Quartz Monzonite are fault contacts, but locally it has definite intrusive relations with limestones of Permian age. The quartz monzonite also apparently is intrusive into lower Mesozoic volcanic rocks that contain exotic blocks of Permian limestones. Elsewhere, the quartz monzonite is overlain by conglomerate assigned to the Glance Conglomerate of the Bisbee Group of Early Cretaceous age. These geologic relations suggest a probable Jurassic age for the quartz monzonite.

THE JACAGUAS GROUP IN CENTRAL-SOUTHERN PUERTO RICO

By Lynn Glover III and Peter H. Mattson

Prepared in cooperation with the Commonwealth of Puerto Rico Economic Development Administration, Industrial Research Department

The Jacaguas Group, herein adopted for use by the U.S. Geological Survey, was named by E. A. Pessagno (1961, p. 351–353) for outcrops along the Río Jacaguas near the town of Juana Díaz (fig. 5). Pessagno recognized that the group was bounded by unconformities and that it contained rocks of middle Eocene age.

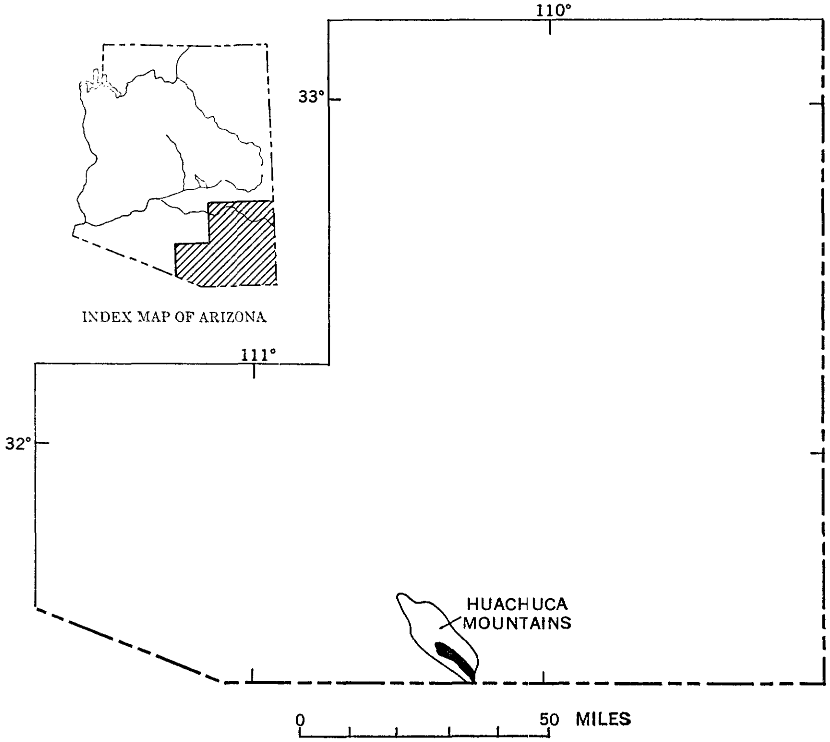


FIGURE 4.—Index map of southeastern Arizona showing location of Huachuca Mountains and Huachuca Quartz Monzonite (black).

Recent work by the authors indicates that abundant dacitic quartz-phenocryst-bearing volcaniclastic rocks are the most characteristic rocks of the group. Thin- (10 cm) to medium-bedded (60 cm) pyroclastic rocks in the east grade westward into thick-bedded (3.6 m) and massive lapilli tuff and tuff breccia. Intercalated with the pyroclastic rocks are beds of limestone and mudstone; conglomerate is common in the basal formation of the group. The Jacaguas Group unconformably overlies the Coamo Formation (Glover, 1961) of Late Cretaceous (Campanian or Maestrichtian) age and older rocks. It is unconformably overlain by middle Tertiary nonvolcanic rocks, including the Oligocene Juana Díaz Formation and the Oligocene and Miocene Ponce Limestone (see Zapp and others, 1948).

Fossils studied by N. F. Sohl (written commun., 1964) indicate that Maestrichtian rocks occur in the base of the Jacaguas Group. At higher stratigraphic levels, Jeremy Reiskind (written commun., 1963) found fossils of Paleocene and early Eocene age. Middle Eocene rocks were documented by Pessagno (1961). The age range of the

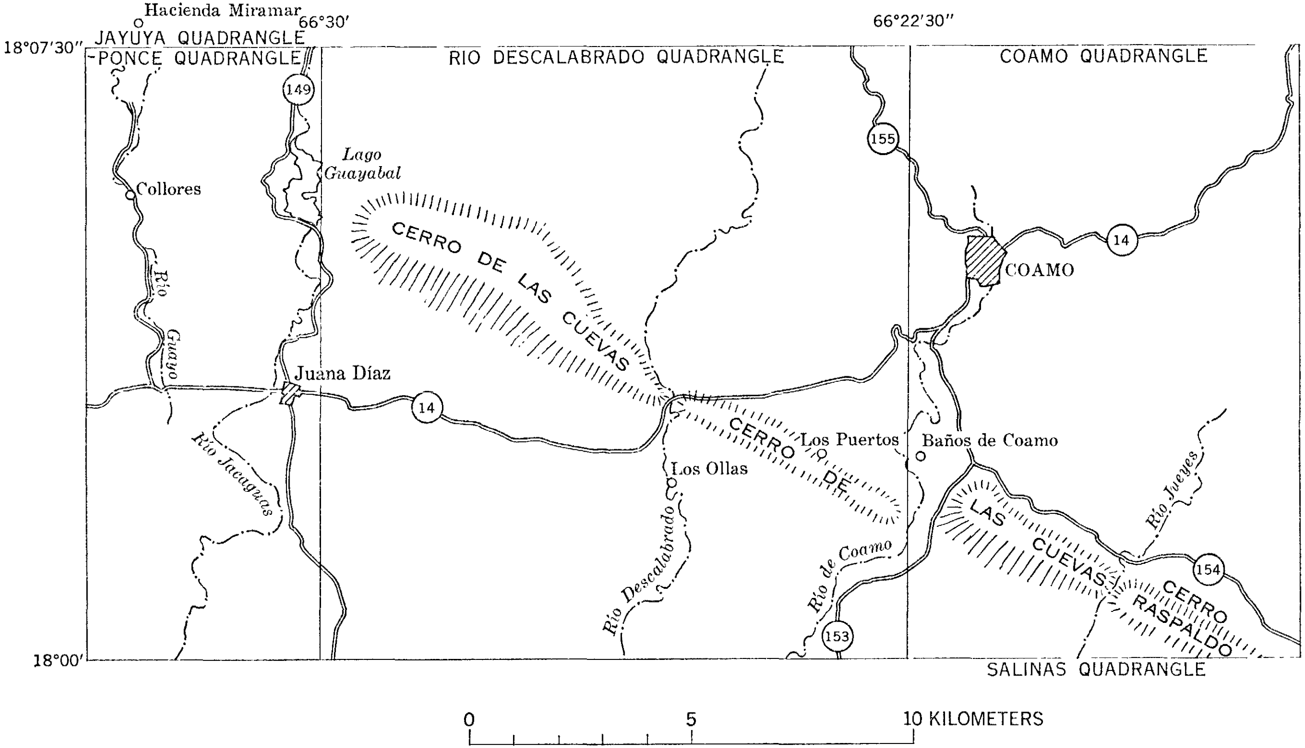


FIGURE 5.—Index map of central-southern Puerto Rico showing localities referred to in text.

SYSTEM	SERIES	GROUP	FORMATION	LITHOLOGY	THICKNESS (METERS)
TERTIARY	Oligocene		Juana Díaz	Limestones and epiclastic rocks	
	UNCONFORMITY				
TERTIARY	Middle Eocene	Jacaguas Group	Río Descalabrado Formation	Dacitic tuffs and mudstones, minor thin limestone lenses, and rare pebble to cobble conglomerate. Mostly thin to medium bedded; common graded bedding and small-scale crossbedding; tuffaceous strata are commonly greenish gray to light-olive gray. Plankton-rich microfauna	>500
TERTIARY	Middle Eocene	Jacaguas Group	Guayo Formation	Conglomeratic lapilli tuff, tuff, and minor mudstone; greenish gray to brown, thick bedded and massive. Interfingers(?) with Río Descalabrado Formation	>200
TERTIARY	Middle(?) to lower(?) Eocene	Jacaguas Group	Cuevas Limestone	Algal limestone (biomicrite with an intact framework of coarse to fine fragments of calcareous red algae); thick bedded or massive, less commonly thin bedded; neariy white, but the basal impure facies may be grayish red	>35
	DISCONFORMITY				
TERTIARY	Lower Eocene to lower Paleocene	Jacaguas Group	Raspaldo Formation	Dacitic tuffs, tuffaceous mudstone, and mudstone, minor limestone, and minor tuffaceous conglomerate. Tuffs and mudstones are light-olive gray, to yellowish gray; thin to medium bedded, with common graded bedding and small-scale crossbedding. The fauna is plankton rich. Rudistids reworked from older formations are common	>600
TERTIARY	Lower Eocene to lower Paleocene	Jacaguas Group	Los Puertos Formation	Tuff breccia, conglomeratic tuff breccia, and tuff; minor limestone; mostly pyroxene- and feldspathic-andesite in massive to thick-bedded units; grayish-red purple to pale brown. Interbeds of plankton-bearing tuffaceous mudstone, some reworked rudistids. Grades laterally into the Raspaldo Formation. Base concealed by faulting	>350
CRETACEOUS	Upper Cretaceous (Maestrichtian)	Jacaguas Group	Miramar Formation	Coarse, red, volcanic wacke conglomerate with abundant reworked dacite tuff; medium- to thick-bedded; contains an oyster-rich limestone at and near the top	700(?)
	UNCONFORMITY				
CRETACEOUS	Rocks of the Coamo Formation (Campanian or Maestrichtian) or older rocks				

FIGURE 6.—Stratigraphic summary of the Jacaguas Group, central-southern Puerto Rico.

group is therefore now considered to be Late Cretaceous (Maestrichtian) to middle Eocene.

Rocks of the Jacaguas Group in central-southern Puerto Rico have been intensely deformed by folding and faulting (Glover and Mattson 1960; Glover, unpub. data), so that some units are repeated at the surface several times (fig. 7). Some stratigraphic units within the group where found only in fault contact with other strata. Nevertheless, several distinctive key lithologies and the common occurrence of diagnostic fossils allow the subdivision of the Jacaguas Group into six formations as shown in figure 6.

The Miramar Formation has been described by Mattson (1966) and the Cuevas Limestone by Glover (1961), but these formations require some comment here. The Raspaldo and Los Puertos Formations are introduced herein. The Guayo Formation is adopted from a report by Pessagno (1960), and the Río Descalabrado Formation is revised from Hodge (1920, p. 161).

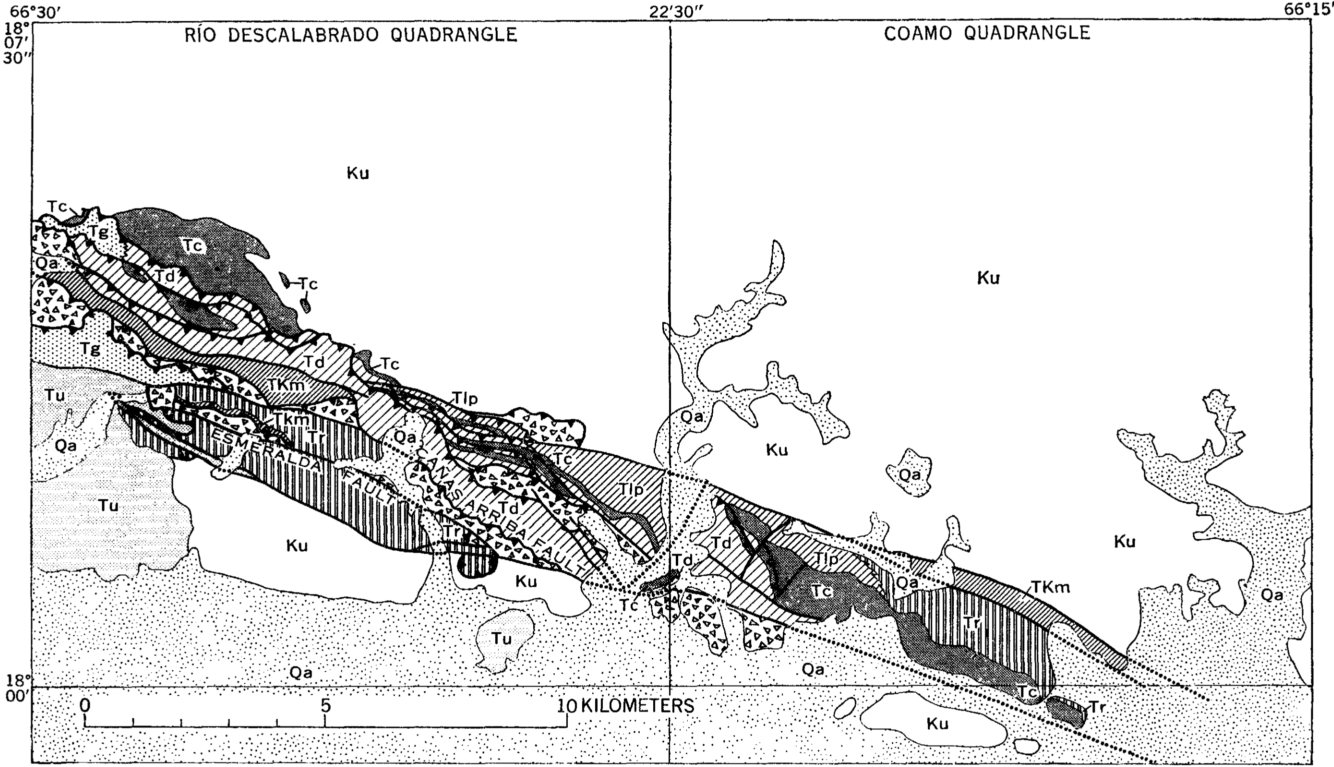
The distribution of the formations composing the Jacaguas Group is shown in figure 7. Thicknesses and brief descriptions are given in figure 6.

MIRAMAR FORMATION

Pessagno (1960) named the Miramar as a member of his Naranjo Formation for outcrops at the base of cliffs about 0.65 km southeast of Hacienda Miramar in southeastern Jayuya quadrangle (fig. 5). At the type locality the Miramar consists of coarse red volcanic wacke conglomerate. It is in uncomformable contact (Mattson, 1966) with the underlying Cariblanco Formation and is overlain by the Cuevas Limestone. The Miramar is herein considered to be the basal formation of the Jacaguas Group in central-southern Puerto Rico. In this area the Miramar comprises as much as 700 m of red generally conglomeratic volcaniclastic rocks similar to those at the type locality.

Pessagno (1960) considered the Miramar to be lower middle Eocene in age because it is overlain with apparent conformity by lower middle Eocene strata. Mattson (1967b) considers it to be of middle Eocene age in the Jayuya quadrangle, but possibly as old as late Paleocene or early Eocene on the basis of some poorly preserved specimens of *Globorotalia velascoensis*. Southeast of the type section the Miramar contains abundant rudistids and is of Late Cretaceous (Maestrichtian) age (N. F. Sohl, written commun., 1964).

Thus the Miramar may be a transgressive unit that ranges in age from Maestrichtian in the southeast to Paleocene(?) and Eocene in the Jayuya quadrangle to the northwest. It correlates in part with the Cuyòn Formation (Glover, this report, p. A18) of southeast-central Puerto Rico and with the San Germán Formation as used by Mattson (1960) of southwestern Puerto Rico.


66°30′
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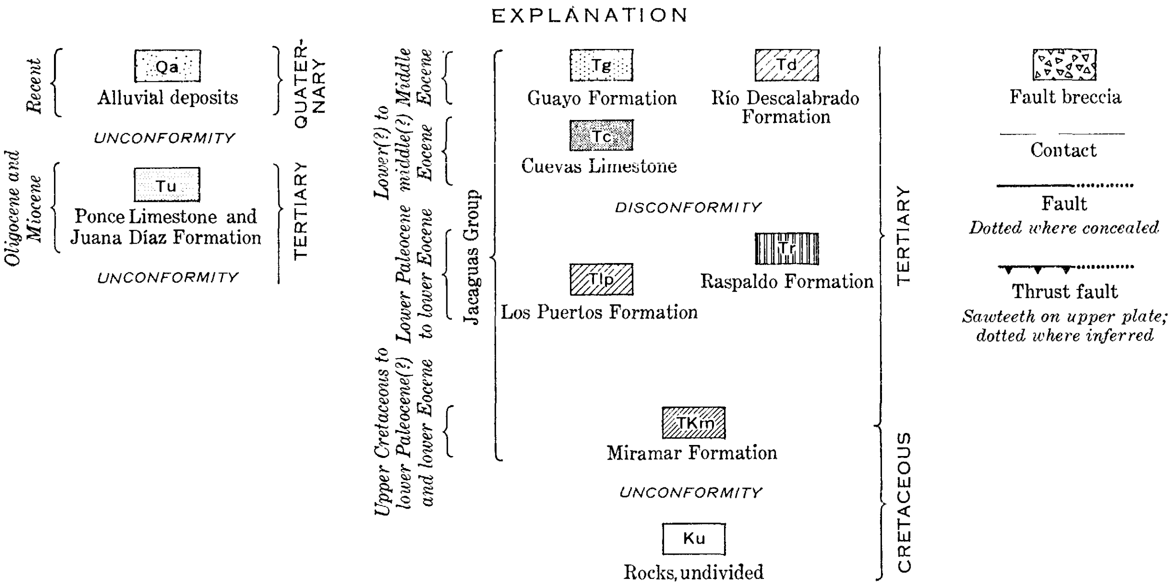

FIGURE 7.—Geologic map of the Jacaguas Group in central-southern Puerto Rico.

RASPALDO FORMATION

The Raspaldo Formation is herein named for a sequence of dominantly thin-bedded volcaniclastic rocks north of Cerro Raspaldo, about 10 km southeast of Coamo (figs. 5 and 7). The base of the Raspaldo is in fault contact with the underlying massive Miramar Formation, and the top of the Raspaldo in is disconformable contact with the younger Cuevas Limestone. North of Cerro de las Cuevas, in the Coamo quadrangle, the Raspaldo grades westward along strike into conglomeratic reworked tuffs of the Los Puertos Formation. South of Cerro de las Cuevas, in the Río Descalabrado quadrangle, the Raspaldo composes the major part of two large gravity glide blocks (fig. 7).

The Raspaldo Formation is principally composed of tuffaceous mudstone, mudstone, and tuff. Less common are limestone and tuffaceous conglomerate. The tuffaceous component is generally dacitic and contains crystals of plagioclase (An_{30-52}) and quartz accompanied by abundant devitrified glass. Limestone occurs locally as one unit but elsewhere as two thin units of algal-rich biomicrite about 3 m thick. The conglomerate is locally a veritable wildflysch of large blocks of Cretaceous conglomerate, tuff breccia, and limestone. The formation probably is more than 600 m thick.

At the type locality the formation contains abundant reworked rudistids which led Glover (1961) to conclude that the sequence was part of the Coamo Formation of Cretaceous age. Subsequently, several foraminiferal collections were obtained from mudstones interbedded with the rudistid-cobble-bearing conglomerate. These microfossils indicate that the Raspaldo is of early Paleocene to early Eocene age (Jeremy Reiskind, written commun., 1962).

The Raspaldo correlates in part with the Jicara Formation as used by Mattson (1960) of southwestern Puerto Rico, and with the unnamed Paleocene or lower Eocene rocks in northeastern Puerto Rico described by Kaye (1956).

LOS PUERTOS FORMATION

Massive tuff breccia and conglomeratic breccia and tuff southeast of Los Puertos (figs. 5 and 7) is herein named the Los Puertos Formation. The base of the formation is concealed by faulting, and the top is disconformably overlain by the Cuevas Limestone. The Los Puertos does not extend far east or west of the type area (fig. 7). On the west it is cut out by a fault, and on the east it grades laterally into the Raspaldo Formation. At the type locality, the Los Puertos is more than 350 m thick.

Rudistids probably reworked from older formations occur in the Los Puertos. A foraminiferal assemblage in a tuffaceous mudstone interbed just north of Cerro de las Cuevas along the west side of the Río Coamo indicates the Los Puertos is early Paleocene and may be in part early Eocene in age (Jeremy Reiskind, written commun., 1962).

CUEVAS LIMESTONE

The Cuevas Limestone was named by Glover (1961) for outcrops on Cerro de las Cuevas in southwestern Coamo quadrangle. The Cuevas is partly equivalent to the Coamo Springs Limestone Series of Hodge (1920). Hodge referred to the "Coamo Springs series," "Coamo Springs limestone series," and "Coamo Springs Formation" as a body of interbedded tuff and limestone gradational toward the top and base into tuff. According to Hodge, "This series is named from a thermal spring located in the Coamo River Water Gap." These springs are known as Baños de Coamo (Coamo Baths), and this name is shown on Hodge's map. The Baños are more than 1 km from the nearest outcrop of the limestone.

Pessagno (1960) chose Coamo Springs Limestone as the variant to revive and considered it a member of his Naranjo Formation. In the absence of a type area designated by Hodge, Pessagno chose the northwestern end of Cerro de las Cuevas in the Río Descalabrado quadrangle about 10 km west of the Baños. Pessagno also extended the name to lenses of limestone "throughout the Descalabrado member" (Miramar, Raspaldo, and Río Descalabrado Formations of this report).

In this report the name Cuevas Limestone is used because: (1) Hodge's names varied, were incorrectly translated, and by the modern stratigraphic code (Am. Comm. on Stratigraphic Nomenclature, 1961, Art. 12(d)) should not be translated. To the writers' knowledge "Coamo Springs" is not a recognized geographic entity. (2) Over much of the area of outcrop, fully half the rock included by Hodge and Pessagno in the "Coamo Springs" is volcaniclastic rock belonging to other formations. Neither recognized that the sequence is repeated by gravity gliding. Thus, under the modern code, extensive redefinition makes it necessary to choose another name.

The Cuevas Limestone (Glover, 1961) is a resistant formation that forms the crest of Cerro de las Cuevas and its extension Cerro Raspaldo in southern Coamo quadrangle. The limestone is about 35 m thick over most of the area but may be thicker in the eastern outcrops. Previous estimates of 800 m by Hodge (1920), 0 to 1,200 m by Pessagno (1960), and 100 m by Glover (1961) were in error because the structure was imperfectly known. The limestone rests disconformably upon the lower Paleocene to lower Eocene Raspaldo Formation and the lower Paleocene and lower Eocene(?) Los Puertos Formation in the Coamo quadrangle, and upon the Los Puertos and Late Cretaceous Coamo Formations in the Río Descalabrado quadrangle. The Cuevas is conformably overlain by the middle Eocene Río Descalabrado Formation. Hence its age is probably middle Eocene, but possibly it may be as old as early Eocene.

RÍO DESCALABRADO FORMATION

The Río Descalabrado is a sequence of well-bedded dacitic tuffs and mudstones more than 500 m thick.

Hodge (1920, p. 161) named the "Río Descalabrados Series" to include "all the strata of the older series occurring above the Coamo Springs limestone" [Cuevas Limestone]. The "series" was named for outcrops along the Río Descalabrado between the Cuevas Limestone and the alluvial-plain deposits to the south as shown in figures 5 and 7. In addition to the post-Cuevas middle Eocene rocks, Hodge inadvertently included many Cretaceous and Paleocene rocks, but his meaning is clear.

Pessagno (1960, p. 78) recognized the Cretaceous rocks south of the Esmeralda fault and excluded them from the sequence. He considered the Río Descalabrado to be a member of his Naranjo Formation and amended the type area to include "rocks west and northwest of Las Ollas." Pessagno did not recognize the complex structure of the rocks north of the Esmeralda fault and also included Paleocene and Cretaceous(?) rocks in the member.

In this report the Río Descalabrado is considered to be a formation. The type section is herein further restricted to include only post-Cuevas rocks similar to those that crop out along the Río Descalabrado between Cerro de las Cuevas and the Cañas Arriba fault a little more than 1 km to the south. In the Coamo area the formation crops out only along the southern flank of Cerro de las Cuevas.

The contact of the Río Descalabrado Formation with the underlying Cuevas Limestone is sharp and conformable; the upper contact is either faulted or unconformable. The Río Descalabrado appears to grade westward into the conglomeratic lapilli tuffs of the Guayo Formation.

Pessagno's (1961, p. 352) fossil localities 103, 104, 154, 155, 222, 228, 229, 241, 242, and 2172 all fall within the Río Descalabrado Formation as here restricted. According to Pessagno, all the faunas from these localities are diagnostic of the *Hantkenina aragonensis* assemblage zone; hence the formation appears to be earliest middle Eocene in age.

GUAYO FORMATION

The Guayo Formation comprises more than 200 m of principally thick-bedded and massive conglomeratic tuff.

Pessagno (1960, p. 85) first proposed the name "Guayo conglomeratic sandstone" for a member of his Naranjo Formation. He designated the type locality as "* * * OP 2396, located in the bed of the Río Guayo (Ponce quad., NE; opposite kilometer post K2H1 on the road to Collores.)." According to his description,

> At the type locality the conglomeratic sandstone contains varicolored, well rounded pebbles and boulders mostly between 1 inch and 1 foot in diameter * * *. However, some boulders occur that are 4 feet * * * or more in diameter. About half of the fragments between 0.06 inch and 1 inch in diameter * * * are angular. There are many fragments of sedimentary rocks such as green siltstones and pyroclastic rocks such as crystal tuffs. Some interbedded medium gray calcilutites, identical to those of the Collores member, are present at the type locality. A characteristic feature of the Guayo conglomeratic sandstone is the large number of pebbles and boulders that are intraformational in origin.
>
> The tuffaceous sandstone which constitutes 70 to 80 percent of the rock consists almost entirely of angular to subangular feldspathic and lithic fragments. Often broken microfossils such as *Discocyclina* and *Operculinoides* are present.

In western Río Descalabrado, Pessagno included all of the Miramar Formation of this report with the correlatives of the Guayo type sequence. His meaning is clear, however, and the name is retained and herein amended to Guayo Formation.

In the Río Descalabrado quadrangle, the contact relations are either faulted or uncertain. Pessagno thought the Guayo interfingered with rocks herein considered part of the Río Descalabrado Formation, and this may be true.

The age of the Guayo Formation can only be estimated from its probable interfingering with the lower middle Eocene Río Descalabrado Formation.

EXSHAW FORMATION OF DEVONIAN AND MISSISSIPPIAN AGE IN NORTHWESTERN MONTANA

By Charles A. Sandberg

The Exshaw Formation of Alberta, which was named by Warren (1937) in the Canadian Rocky Mountains, is here recognized to extend southward in the subsurface into the United States. It underlies parts of Glacier, Toole, Liberty, Pondera, and Teton Counties in northwestern Montana (fig. 8).

The name Exshaw Shale was applied by Warren (1937) to exposures of black fissile shale in Jura Creek, 1 mile east of the town of Exshaw, Alberta, and 2 miles north of the highway between Calgary and Banff. At its type locality, the Exshaw unconformably overlies the Palliser Formation of Late Devonian age and underlies with gradational contact the Banff Formation of Early Mississippian age. The upper contact of the Exshaw was revised by Clark (1949) and Harker and McLaren (1958) to include black argillaceous and silty massive limestone that overlies the black shale.

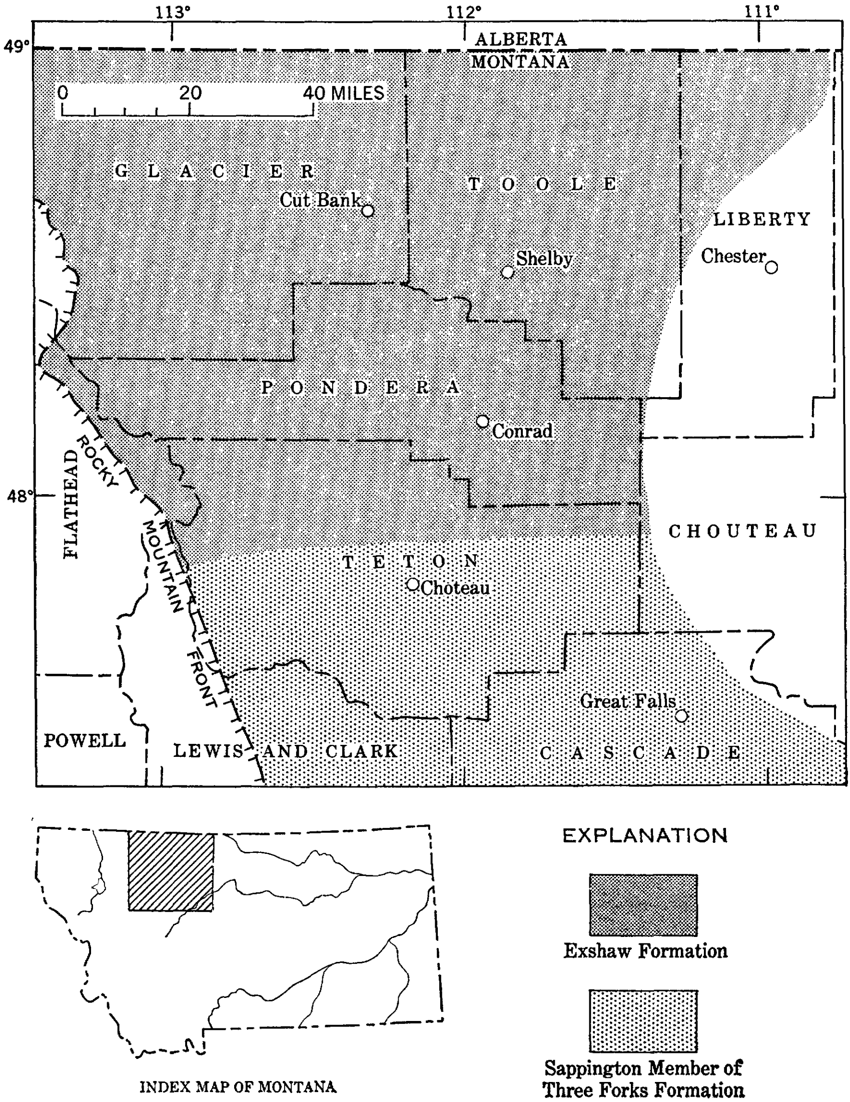

FIGURE 8.—Index map of northwestern Montana showing areas underlain by Exshaw Formation and Sappington Member of Three Forks Formation.

The term Exshaw Formation was used by Harker and McLaren (1958), who described its stratigraphy in detail and presented 22 measured sections. These sections demonstrate that the formation, in its fullest development, comprises a basal sandstone member only a few tenths of an inch thick, a shale member, and a limestone and siltstone member.

The following measured section of the Exshaw Formation at its type locality was presented by Harker and McLaren (1958, p. 255, sec. 7):

	Thickness (feet)
Exshaw Formation:	
Limestone member:	
3. Limestone, black, argillaceous, quartzose, silty; scattered pyrite nodules; weathers rusty brown; poorly preserved brachiopods at top of unit; pelecypods, goniatites, orthoceratids, and trilobite in lower 2 ft	37
Shale member:	
2. Shale, black, noncalcareous; pyritic concretions in lower 4 ft and disseminated pyrite throughout; weathers dark gray with reddish-brown staining	31
Sandstone member:	
1. Sandstone, quartzose, dark-gray, pyritic, calcareous, phosphatic, coarse-grained; abundant fragments of bone, chert, and indurated black shale	.17
Total thickness of Exshaw Formation	68.17

The Exshaw Formation was correlated by Sandberg (1965, p. N16–N17) with both the Sappington Member of the Three Forks Formation and the Bakken Formation. The Exshaw, Sappington, and Bakken originally were connected depositionally, but they now are partly separated because of Early Mississippian erosion. A basal black shale is continuous among all three units. The upper siltstone of the Exshaw is separated from the upper siltstone of the Sappington in southwestern Montana by an erosional area about 40 miles wide. In northernmost Montana the upper siltstone of the Exshaw is separated from the medial siltstone of the Bakken on the east by an erosional area about 30 miles wide, but in southern Alberta the two siltstones are continuous.

The age of the Exshaw Formation was regarded as Devonian by Warren (1937) but as Mississippian by Crickmay (1952) and many other later workers. In the subsurface of southern Alberta, however, the basal black shale, which is continuous between the Exshaw and Bakken Formations, contains an Upper Devonian conodont fauna (Klapper, 1966, p. 10). Because the Exshaw apparently contains both Devonian and Mississippian fossils in Alberta and is continuous with the Sappington Member of the Three Forks Formation and the Bakken Formation, both of Devonian and Mississippian age, the Exshaw in northwestern Montana is considered to be Devonian and Mississippian.

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