U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Bandelier National Monument

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Bandelier National Monument

band_geology.pdf

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Geologic Resources Inventory Map Document for Bandelier National Monument

Table of Contents

Geologic Resources Inventory Map Document **1**
About the NPS Geologic Resources Inventory Program **2**
Map Unit List **4**
Map Unit Descriptions **10**
Qaf - Artificial fill (latest Holocene) 10
Qdi - Disturbed areas (Holocene) 10
Qtp - Piedmont alluvium (Holocene) 10
Qal - Alluvium (Holocene to Pleistocene) 11
Qfa - Alluvial fan deposits (Holocene to middle Pleistocene) 12
Qafu - Alluvial fans, difficult to distinguish from older fans (late Holocene to late Pleistocene) 13
Qa5 - Alluvial deposit, beds of sand (Holocene to late Pleistocene) 14
Qp5 - Piedmont alluvial deposit, sand and gravel (Holocene to late Pleistocene) 14
Qpa - Alluvial and eolian deposit (Holocene to Pleistocene) 14
Qls - Landslides (Holocene to Pleistocene) 16
Qc - Colluvium (Holocene to Pleistocene) 18
Qcbt - Colluvium, wedge shaped deposits of Tshirege Member of Bandelier Tuff (Holocene to Pleistocene) 19
Qcta - Cerro Toledo deposits with younger alluvium and/or colluvium, undivided (Holocene to Pleistocene) 19
Qt - Terrace gravel (Holocene to Pleistocene) 20
Qac - Alluvium and colluvium, undivided (Holocene and late Pleistocene?) 20
Qpct1 - Terrace gravel, Pueblo Canyon upper terrace level (Holocene to Pleistocene) 21
Qpct2 - Terrace gravel, Pueblo Canyon lower terrace level (Holocene to Pleistocene) 21
Qfd - Fan alluvium and debris-flow deposits, undivided (Holocene to Pleistocene) 21
Qrx - Boulder fields (Holocene to Pleistocene) 21
Qyt - Younger stream terraces (Holocene (inferred) or late Pleistocene) 22
Qts - Sulphur Creek terraces (Holocene to late Pleistocene) 22
Qlso - Older landslides (late Pleistocene) 22
Qto - Older stream terraces (late Pleistocene) 22
Qa4 - Alluvial deposit , gravel and sand (late Pleistocene) 22
Qp4 - Piedmont alluvial deposit, gravel, sand and silty sand (late Pleistocene) 23
Qalo2 - Old alluvium (Pleistocene) 23
Qtpu - Piedmont alluvium, undivided (late to early(?) Pleistocene) 23
Qafo - Older alluvial fans (Pleistocene) 23
Qlec - El Cajete lake deposits (Pleistocene) 24
Qlb - El Cajete lake deposits, constructional landforms (Pleistocene) 24
Ql - Lacustrine deposits in northern caldera (Pleistocene) 24
Qlsm - South Mountain lake deposits (Pleistocene) 24
Qso - Older intracaldera sandstone (Pleistocene) 24
Qmso - Older sedimentary deposits of northern caldera (Pleistocene) 24
Qdf - Early caldera-fill debris-flow , landslide, alluvium, and colluvium deposits (Pleistocene) 25
Qvsc - Early caldera-fill lacustrine and fluvial deposits, abundant biotite from weathered Redondo Creek rhyodacite (Pleistocene) 25
Qst - Sinter deposits (Pleistocene) 25
Qvs - Early caldera-fill lacustrine and fluvial deposits (Pleistocene) 25
Qvb - Valles Rhyolite, Banco Bonito Flow (Pleistocene) 25
Qg3 - Sedimentary deposits of southern caldera, episode 3 (Pleistocene) 25

Qvec - Valles Rhyolite, El Cajete Pyroclastic Beds (Pleistocene) 26
Qvbr - Valles Rhyolite, Battleship Rock Ignimbrite (Pleistocene) 28
Qg2 - Sedimentary deposits of southern caldera, episode 2 (Pleistocene) 28
Qvsm4 - Valles Rhyolite, South Mountain Member, fourth flow (Pleistocene) 28
Qvsm3 - Valles Rhyolite, South Mountain Member, third flow (Pleistocene) 28
Qvsm2 - Valles Rhyolite, South Mountain Member, second flow (Pleistocene) 28
Qvsm1 - Valles Rhyolite, South Mountain Member, first flow (Pleistocene) 28
Qvlj - Valles Rhyolite, Cerro La Jara rhyolite (Pleistocene) 29
Qg1 - Sedimentary deposits of southern caldera, episode 1 (Pleistocene) 29
Qvsa3 - Valles Rhyolite, San Antonio Mountain Member, flow 3 and peripheral vent (Pleistocene) 29
Qvsa2 - Valles Rhyolite, San Antonio Mountain Member, flow 2 (Pleistocene) 29
Qvsa1 - Valles Rhyolite, San Antonio Mountain Member, flow 1 (Pleistocene) 29
Qvse2 - Valles Rhyolite, Cerro Seco Member, flow 2 (Pleistocene) 29
Qvse1 - Valles Rhyolite, Cerro Seco Member, flow 1 (Pleistocene) 29
Qvset - Valles Rhyolite, Cerro Seco Member, pyroclastic deposits (Pleistocene) 30
Qtoal - Valles Rhyolite, Older alluvium (Pleistocene) 30
Qvsl2 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 2 (Pleistocene) 31
Qvsl1 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 1 (Pleistocene) 31
Qvsr2 - Valles Rhyolite, Cerro Santa Rosa Member, north dome (Pleistocene) 31
Qvsr1 - Valles Rhyolite, Cerro Santa Rosa Member, south dome (Pleistocene) 31
Qvsrt - Valles Rhyolite, Cerro Santa Rosa Member, pyroclastic flow (Pleistocene) 32
Qvda4 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, small sanidine phenocrysts (Pleistocene) 32
Qvda3 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, large sanidine phenocrysts (Pleistocene) 32
Qvda2 - Valles Rhyolite, Cerros del Abrigo Member, perlitic lava (Pleistocene) 32
Qvda1 - Valles Rhyolite, Cerros del Abrigo Member, perlitic porphyritic lava (Pleistocene) 32
Qvdmt - Valles Rhyolite, Cerro del Medio Member, pyroclastic flow and pumice fall deposits (Pleistocene) 32
Qvdm6 - Valles Rhyolite, Cerro del Medio Member, massive devitrified vesicular lava (Pleistocene) 33
Qvdm5 - Valles Rhyolite, Cerro del Medio Member, upheaved dome of glassy to devitrified lava (Pleistocene) 33
Qvdm4 - Valles Rhyolite, Cerro del Medio Member, massive aphyric obsidian flow (Pleistocene) 33
Qvdmn - Valles Rhyolite, Cerro del Medio Member, vesicular flow-baned glassy to devitrified lava (Pleistocene) 33
Qvdmw - Valles Rhyolite, Cerro del Medio Member, obsidian flow (Pleistocene) 33
Qvdms - Valles Rhyolite, Cerro del Medio Member, flow-banded sparsely porphyritic lava (Pleistocene) 33
Qrc - Valles Rhyolite, Redondo Creek Member (Pleistocene) 34
Qrd2 - Valles Rhyolite, Young Rabbit Mountain debris-flow deposits (Pleistocene) 34
Qdc - Valles Rhyolite, Deer Canyon Member (Pleistocene) 34
Qdct - Valles Rhyolite, Deer Canyon Member, lithic and crystal rich thin-bedded rhyolitic tuffs (Pleistocene) 34
Qcvm - Cerro Toledo Formation, Virgin Mesa Member (Pleistocene) 34
Qcpc - Cerro Toledo Formation, Pueblo Canyon Member (Pleistocene) 34
Qcr - Cerro Toledo Formation, aphyric rhyolite (Pleistocene) 35
Qcrt - Cerro Toledo Formation, Valle Toledo Member, Rhyolite tuff (Pleistocene) 35
Qcws - Cerro Toledo Formation, Valle Toledo Member, Warm Springs rhyolite (Pleistocene) 35
Qctq - Cerro Toledo Formation, Valle Toledo Member, Cerro Trasquilar rhyolite (Pleistocene) 35
Qrd1 - Cerro Toledo Formation, Valle Toledo Member, Old Rabbit Mountain debris-flow deposits (Pleistocene) 35
Qcs - Cerro Toledo Formation, Valle Toledo Member, Sierra de Toledo rhyolite (Pleistocene) 35
Qctr - Cerro Toledo Formation, Valle Toledo Member, Turkey Ridge rhyolite (Pleistocene) 36
Qcrm - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite (Pleistocene) 36
Qcrmt - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite, bedded tuff (Pleistocene) 36
Qnd - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte debris avalanche deposit (Pleistocene) 36
Qct - Cerro Toledo Formation, Valle Toledo Member (Pleistocene) 36
Qcep - Cerro Toledo Formation, Valle Toledo Member, East Los Posos rhyolite (Pleistocene) 37
Qci - Cerro Toledo Formation, Valle Toledo Member, Indian Point rhyolite (Pleistocene) 38
Qcnp - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite (Pleistocene) 38
Qcnpt - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite, lithic rich tuff (Pleistocene) 38

Qcnr - Cerro Toledo Formation, Valle Toledo Member, north caldera rim intrusion (Pleistocene) 38
Qcwp - Cerro Toledo Formation, Valle Toledo Member, West Los Posos rhyolite (Pleistocene) 38
Qbx - Bandelier Tuff, vent and/or hydrothermal breccia (Pleistocene) 38
Qbt - Bandelier Tuff, Tshirege Member (Pleistocene) 39
Qxbo - Bandelier Tuff, caldera-collapse breccia, Bandelier Tuff, Otowi Member (Pleistocene) 41
Qxt - Bandelier Tuff, caldera-collapse breccia, Tschicoma and Puye Formations (Pleistocene) 41
Qxpt - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation dacite tuff (Pleistocene) 41
Qxp - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation andesite and volcaniclastic materials (Pleistocene) 42
Qxsf - Bandelier Tuff, caldera-collapse breccia, Santa Fe Group (Pleistocene) 42
Qxr - Bandelier Tuff, caldera-collapse breccia, Ritito Formation (Pleistocene) 42
Qxa - Bandelier Tuff, caldera-collapse breccia, Abo Formation and Yeso Group (Pleistocene) 42
Qxm - Bandelier Tuff, caldera-collapse breccia, Madera Formation (Pleistocene) 42
Qbo - Bandelier Tuff, Otowi Member (Pleistocene) 42
Qbog - Bandelier Tuff, Guaje Pumice Bed (Pleistocene) 45
Qgo - Bandelier Tuff, older gravels (Pleistocene) 45
Qt3 - Terrace gravel, correlative with Santo Domingo Pueblo terraces (middle Pleistocene) 45
Qt2 - Terrace gravel, correlative with Canada terrace of Aby (1997) (middle Pleistocene) 46
Qt1 - Terrace gravel, former courses of Peralta and Cochiti Canyons (middle Pleistocene) 46
Qa3 - Alluvial deposit, boulder gravel and cross-bedded sand (middle Pleistocene) 46
Qp3 - Piedmont alluvial deposit, poorly sorted gravel and sand (middle Pleistocene) 47
Qa2 - Alluvial deposit, cobble and boulder gravel (middle? Pleistocene) 47
Qp2 - Piedmont alluvial deposit, gravel, silt and massive sand (middle? Pleistocene) 48
Qa1 - Alluvial deposit, cobble and boulder gravel with beds of coarse sand (early Pleistocene) 48
Qp1 - Piedmont alluvial deposit, gravel (early? Pleistocene) 48
Qba - Basaltic alluvium (early? to middle? Pleistocene) 49
Qcuc - Andesite of Cochiti Volcano, upper unit, cinder deposits (early Pleistocene) 49
Qcu - Andesite of Cochiti Volcano, upper unit, lava flows (early Pleistocene) 49
Andesite of Little Cochiti cone (early Pleistocene) 50
    Qlcc - cinder deposits (early Pleistocene) 50
    Qlc - lava flows (early Pleistocene) 50
Qd - Dacite of Arroyo Montoso (early Pleistocene) 51
Qcl - Andesite of Cochiti Volcano, lower unit (early Pleistocene) 51
Qacl - Basaltic andesite of Cochiti Lake (early Pleistocene) 51
QTtp - Piedmont alluvium (early Pleistocene(?) and late Pliocene) 51
QTcrv - Cerros del Rio volcanic rocks (lower Pleistocene to upper Pliocene) 52
QTbt - Basaltic tephra (lower Pleistocene to upper Pliocene) 52
QTa - Ancha Formation (lower Pleistocene to upper Pliocene) 53
QTslg - Sierra Ladrones Formation (lower Pleistocene to upper Miocene) 54
QTc - Cochiti Formation (lower Pleistocene to Miocene) 54
QTsfa - Santa Fe Group, axial channel facies (lower Pleistocene and Pliocene) 55
QTpf - Puye Formation (lower Pleistocene to lower Pliocene) 55
QTpt - Puye Formation, ancestral Rio Grande facies (lower Pleistocene to lower Pliocene) 57
Tpl - Puye Formation, lacustrine facies (late(?) Pliocene) 57
Tpi - Puye Formation, interbedded thin beds of tephras and/or ignimbrites (Pliocene) 58
Tog - Old fluvial gravel (upper Pliocene (?)) 58
Basalt of Hill 7033 58
    Tbxc - cinder deposits (Tertiary) 58
    Tbx - lava flows (Tertiary) 59
Andesite of Ortiz Mountain 59
    Toc - cinder deposits (Tertiary) 59
    To - lava flows (Tertiary) 59
Basaltic andesite of Twin Hills 59
    Ttoc - cinder deposits (Tertiary) 59

Tto - lava flows (Tertiary) 59
Basalt of Hill 7065 60
Ttdc - cinder deposits (Tertiary) 60
Ttd - lava flows (Tertiary) 60
Basalt of Tetilla Hole 60
Tbtc - cinder deposits (Tertiary) 60
Tbt - lava flows (Tertiary) 61
Basalt of Colorado Peak 61
Tcpcd - cinder deposits (Tertiary) 61
Tcb - lava flows (Tertiary) 61
Basalt of Cañada Ancha 61
Tbuc - cinder deposits (Tertiary) 61
Tbu - lava flows (Tertiary) 62
Basalt of Hill 6929 62
Tbzc - cinder deposits (Tertiary) 62
Tbz - lava flows (Tertiary) 62
Basaltic andesite of Arroyo Eighteen 62
Taec - cinder deposits (Tertiary) 62
Tae - lava flows (Tertiary) 63
Tclf - Mafic lava flows (Pliocene) 63
Tcba - Benmorite (Pliocene) 63
Tcbc - Cinder deposit (Pliocene) 63
Tcbm - Mafic hydromagmatic deposits (Pliocene) 64
Tglp - Gravel of Lookout Park (Pliocene to Miocene) 64
Ttqc - Tschicoma Formation, upper Quemazon Canyon dacite (Pliocene) 64
Ttcb - Tschicoma Formation, Caballo Mountain dacite (Pliocene) 64
Ttpm - Tschicoma Formation, Pajarito Mountain dacite (Pliocene) 65
Ttcg - Tschicoma Formation, Cerro Grande dacite (Pliocene) 65
Ttsd - Tschicoma Formation, Sawyer Dome dacite (Pliocene) 66
Ttcr - Tschicoma Formation, Cerro Rubio dacite (Pliocene) 66
Ttcd - Tschicoma Formation, dacite intrusion north of Cerro Rubio (Pliocene) 66
Ttsc - Tschicoma Formation, Santa Clara Canyon dacite (Pliocene) 66
Ttpd - Tschicoma Formation, Tschicoma Peak area dacite and rhyodacite, undivided (Pliocene) 66
Ttrc - Tschicoma Formation, Rendija Canyon rhyodacite (Pliocene) 67
Ttrb - Tschicoma Formation, breccia, white to gray ignimbrite and tephra (Pliocene) 67
Tti - Tschicoma Formation, small-volume ignimbrites in upper Guaje Canyon, west of the reservoir (Pliocene) 67
Tbh - Bearhead Rhyolite (Pliocene to Miocene) 67
Ttxc - Basaltic andesite of Thirty-One Draw, cinder deposits (Pliocene) 69
Ttx - Basaltic andesite of Thirty-One Draw, lava flows (Pliocene) 69
Tayc - Basalt of Caja del Rio, cinder deposits (Pliocene) 69
Tay - Basalt of Caja del Rio, lava flows (Pliocene) 69
Tmc - Basalt of Montoso Peak, cinder deposits (Pliocene) 69
Tmpb - Basalt of Montoso Peak, lava flows (Pliocene) 69
Tcpc - Andesite of Cerrita Portillo, cinder deposits (Pliocene) 69
Tcp - Andesite of Cerrita Portillo, lava flows (Pliocene) 70
Tbclc - Basaltic andesite of Arroyo Calabasas, cinder deposits (Pliocene) 70
Tbclf - Basaltic andesite of Arroyo Calabasas, lava flows (Pliocene) 70
Tb - Basalt of La Bajada Rim (Pliocene) 70
Tbsc - Basalt of Tsinat Mesa, cinder deposits (Pliocene) 71
Tbs - Basalt of Tsinat Mesa, lava flows (Pliocene) 71
Tbcc - Basaltic andesite of Cerro Micho, cinder deposits (Pliocene) 71
Tbc - Basaltic andesite of Cerro Micho, lava flows (Pliocene) 71
Tbhm - Hydromagmatic deposits (Pliocene) 71
Tbcl - Basalt of Cochiti Lake (Pliocene) 71

Tcac - Andesite of Colorado Peak, cinder deposits (Pliocene) 72
Tca - Andesite of Colorado Peak, lava flows (Pliocene) 72
Tat - Andesite of Tetilla Peak (Pliocene) 72
Tas - Andesite of Sanchez Canyon (Pliocene) 72
Tcmc - Andesite of Cerro Micho, cinder deposits (Pliocene) 73
Tcm - Andesite of Cerro Micho, lava flows (Pliocene) 73
Taba - Andesite and basaltic andesite, undivided (Pliocene) 73
Tbi - Bearhead Rhyolite, intrusions (upper Miocene) 73
Tkpt - Bearhead Rhyolite, Peralta Tuff Member (Miocene) 74
Tsf - Santa Fe Group, undivided (Miocene) 75
Tstv - Volcaniclastic sediments (Miocene to upper Oligocene) 76
Tscv - Chamita Formation, lower Vallito Member (Miocene) 77
Tscu - Chamita Formation, Hernandez Member (Miocene) 77
Tcar - Chamita Formation, axial river sediment (upper middle Miocene to upper Miocene) 77
Tccu - Chamita Formation, Cuarteles Member (upper middle Miocene to upper Miocene) 78
Tccuf - Chamita Formation, Cuarteles Member, fine-grained, distal sediment (upper middle Miocene to upper Miocene) 78
Tstb - Tesuque Formation, basalt flow (Miocene to upper Oligocene) 78
Tstc - Tesuque Formation, Chama-El Rito Member (Miocene) 78
Ttcu - Tesuque Formation, Cuarteles Member (upper middle Miocene to upper Miocene) 78
Ttcuf - Tesuque Formation, Cuarteles Member, fine-grained, distal sediment (upper middle Miocene to upper Miocene) 79
Tsfb - Basalt flows and cinders (late Miocene) 80
Tscc - Cerro Conejo Formation (Miocene) 80
Tqv - Quartz veins (Miocene) 80
Tghd - La Grulla Formation, hornblende dacite and rhyodacite (Miocene) 80
Tgbhd - La Grulla Formation, porphyritic biotite, hornblende rhyodacite (Miocene) 80
Tgb - La Grulla Formation, olivine basalt (Miocene) 81
Tga - La Grulla Formation, porphyritic andesite and dacite, undivided (Miocene) 81
Tpgd - Dacite outcrop in Guaje Canyon (Miocene) 81
Tpv - Paliza Canyon Formation, volcaniclastic member, conglomerate sandstone (Pliocene? to Miocene) 81
Tpvs - Paliza Canyon Formation, volcaniclastic member, sandstone (Pliocene? to Miocene) 82
Tpb - Paliza Canyon Formation, olivine basalt and basaltic andesite, undivided (Miocene) 83
Tpa - Paliza Canyon Formation, Two-pyroxene andesite, undivided (Miocene) 84
Tpbhd - Paliza Canyon Formation, porphyritic biotite, hornblende dacite (Miocene) 85
Tpmc - Paliza Canyon Formation, trachyandesite of Mesita Cocida (Miocene) 87
Tpai - Paliza Canyon Formation, andesite dikes that may be the source of the trachyandesite of Mesita Cocida (Miocene) 87
Thb - Paliza Canyon Formation, hydrothermal breccia (Miocene) 87
Tpdt - Paliza Canyon Formation, porphyritic dacite tuff (Miocene) 87
Tpd - Paliza Canyon Formation, aphyric dacite (Miocene) 88
Tpbd - Paliza Canyon Formation, porphyritic biotite dacite (Miocene) 88
Tpbb - Paliza Canyon Formation, basalt of Bodega Butte (Miocene) 89
Tpbbs - Paliza Canyon Formation, scoria facies of basalt of Bodega Butte (Miocene) 89
Tpbt - Paliza Canyon Formation, basalt, hydromagmatic tephra (Miocene) 90
Tpbi - Paliza Canyon Formation, basalt, Basaltic dikes (Miocene) 90
Tppa - Paliza Canyon Formation, porphyritic andesite (Miocene) 90
Tphd - Paliza Canyon Formation, porphyritic hornblende dacite (Miocene) 91
Tpha - Paliza Canyon Formation, hornblende andesite (Miocene) 91
Tm - Paliza Canyon Formation, Monzonite dikes and stocks (Miocene) 91
Tct - Canovas Canyon Rhyolite lavas (Miocene) 92
Tcct - Canovas Canyon Rhyolite (Miocene) 92
Tcc - Canovas Canyon Rhyolite, domes, flows, and intrusions (Miocene) 93
Tpoa - Olivine andesite (Miocene) 94
Tpcm - Basalt of Chamisa Mesa (Miocene) 95

Tbm - Bland monzonite (Miocene) 95
Tlb - Polvadera Group volcanic rocks (Miocene) 95
Ta - Abiquiu Formation (Miocene to Oligocene) 96
Tgs - Galisteo Formation (Eocene) 96
TRcu - Upper Chinle Group, undivided (Triassic) 96
TRcs - Shinarump Formation (Triassic) 96
TRm - Moenkopi Formation (Triassic) 97
Pg - Glorieta Sandstone (Permian) 97
Py - Yeso Group (Permian) 97
Geologic Cross Sections 98
GRI Source Map Citations 102
Preliminary Geologic Map of the Bland Quadrangle 103
Report 103
Correlation 103
Index and Location Map 104
Legend 104
References 105
Geologic Map of the Cochiti Dam Quadrangle 105
Introduction 105
Correlation 106
Landsat Image 1 107
Landsat Image 2 108
Table 1 - Characteristics of Cerros del Rio Volcanic Field Deposits 109
Table 2 - Geologic Sample Coordinates 109
Location and Generalized Geologic Map 110
Index Map 111
Legend 112
References 113
Geologic Map of the Valles Caldera 113
Report 113
Correlation 114
Index and Location Map 115
Legend 116
Geologic Map of the Guaje Mountain Quandrangle 117
Report 117
Correlation 117
Index and Location Map 118
Legend 118
Geologic Map of the Montoso Peak Quadrangle 119
Correlation 119
Table 1 - Characteristics of Cerros del Rio Volcanic Field Deposits 120
Table 2 - Analysis Data for Geologic Samples 121
Index Map 122
Legend 123
Geologic Map of the Southern Espanola Basin 123
Report 123
Correlation 124
Legend 125
Location Map and Source Map Index 126
References 127
Preliminary Geologic Map of the Redondo Peak Quadrangle 128
Report 128
Correlation 128

Legend 129
Index and Location Map 129
Preliminary Geologic Map of the Canada Quadrangle 129
Report 129
Correlation 130
Index of Map Sources 130
Legend 131
References 132
Preliminary Geologic Map of the Frijoles Quadrangle 132
Report 133
Correlation 133
Index and Location Map 134
Legend 135
Preliminary Geologic Map of the Bear Springs Peak Quandrangle 135
Report 135
Correlation 136
Index and Location Map 137
Legend 137
References 138
Geologic Map of the Puye Quadrangle 138
Correlation 139
Location Map 139
Legend 140
References 141
GRI Digital Data Credits 142

Geologic Resources Inventory Map Document

Bandelier National Monument, New Mexico

Document to Accompany Digital Geologic-GIS Data

band_geology.pdf

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This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Bandelier National Monument, New Mexico (BAND).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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Map Unit List

The geologic units present in the digital geologic-GIS data produced for Bandelier National Monument, New Mexico (BAND) are listed below. Units are listed with their assigned unit symbol and unit name (e. g., Qaf - Artificial fill). Units are generally listed from youngest to oldest. Information about each geologic unit is also presented in the Geologic Unit Information (BANDUNIT) table included with the GRI geologic-GIS data.

Geologic Map Units

Geologic Era (e.g, Cenozoic Era)

Quaternary Period

Qaf - Artificial fill (Qaf)
Qdi - Disturbed areas (Qdi)
Qtp - Piedmont alluvium (Qtp)
Qal - Alluvium (Qal)
Qfa - Alluvial fan deposits (Qfa)
Qafu - Alluvial fans, difficult to distinguish from older fans (Qafu)
Qa5 - Alluvial deposit, beds of sand (Qa5)
Qp5 - Piedmont alluvial deposit, sand and gravel (Qp5)
Qpa - Alluvial and eolian deposit (Qpa)
Qls - Landslides (Qls)
Qc - Colluvium (Qc)
Qcbt - Colluvium, wedge shaped deposits of Tshirege Member of Bandelier Tuff (Qcbt)
Qcta - Cerro Toledo deposits with younger alluvium and/or colluvium, undivided (Qcta)
Qt - Terrace gravel (Qt)
Qac - Alluvium and colluvium, undivided (Qac)
Qpct1 - Terrace gravel, Pueblo Canyon upper terrace level (Qpct1)
Qpct2 - Terrace gravel, Pueblo Canyon lower terrace level (Qpct2)
Qfd - Fan alluvium and debris-flow deposits, undivided (Qfd)
Qrx - Boulder fields (Qrx)
Qyt - Younger stream terraces (Qyt)
Qts - Sulphur Creek terraces (Qts)
Qlso - Older landslides (Qlso)
Qto - Older stream terraces (Qto)
Qa4 - Alluvial deposit , gravel and sand (Qa4)
Qp4 - Piedmont alluvial deposit, gravel, sand and silty sand (Qp4)
Qalo2 - Old alluvium (Qalo2)
Qtpu - Piedmont alluvium, undivided (Qtpu)
Qafo - Older alluvial fans (Qafo)
Qlec - El Cajete lake deposits (Qlec)
Qlb - El Cajete lake deposits, constructional landforms (Qlb)
Ql - Lacustrine deposits in northern caldera (Ql)
Qlsm - South Mountain lake deposits (Qlsm)
Qso - Older intracaldera sandstone (Qso)
Qmso - Older sedimentary deposits of northern caldera (Qmso)
Qdf - Early caldera-fill debris-flow, landslide, alluvium, and colluvium deposits (Qdf)
Qvsc - Early caldera-fill lacustrine and fluvial deposits, abundant biotite from weathered Redondo Creek rhyodacite (Qvsc)
Qst - Sinter deposits (Qst)

Qvs - Early caldera-fill lacustrine and fluvial deposits (Qvs)
Qvb - Valles Rhyolite, Banco Bonito Flow (Qvb)
Qg3 - Sedimentary deposits of southern caldera, episode 3 (Qg3)
Qvec - Valles Rhyolite, El Cajete Pyroclastic Beds (Qvec)
Qvbr - Valles Rhyolite, Battleship Rock Ignimbrite (Qvbr)
Qg2 - Sedimentary deposits of southern caldera, episode 2 (Qg2)
Qvsm4 - Valles Rhyolite, South Mountain Member, fourth flow (Qvsm4)
Qvsm3 - Valles Rhyolite, South Mountain Member, third flow (Qvsm3)
Qvsm2 - Valles Rhyolite, South Mountain Member, second flow (Qvsm2)
Qvsm1 - Valles Rhyolite, South Mountain Member, first flow (Qvsm1)
Qvlj - Valles Rhyolite, Cerro La Jara rhyolite (Qvlj)
Qg1 - Sedimentary deposits of southern caldera, episode 1 (Qg1)
Qvsa3 - Valles Rhyolite, San Antonio Mountain Member, flow 3 and peripheral vent (Qvsa3)
Qvsa2 - Valles Rhyolite, San Antonio Mountain Member, flow 2 (Qvsa2)
Qvsa1 - Valles Rhyolite, San Antonio Mountain Member, flow 1 (Qvsa1)
Qvse2 - Valles Rhyolite, Cerro Seco Member, flow 2 (Qvse2)
Qvse1 - Valles Rhyolite, Cerro Seco Member, flow 1 (Qvse1)
Qvset - Valles Rhyolite, Cerro Seco Member, pyroclastic deposits (Qvset)
Qtoal - Valles Rhyolite, Older alluvium (Qtoal)
Qvsl2 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 2 (Qvsl2)
Qvsl1 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 1 (Qvsl1)
Qvsr2 - Valles Rhyolite, Cerro Santa Rosa Member, north dome (Qvsr2)
Qvsr1 - Valles Rhyolite, Cerro Santa Rosa Member, south dome (Qvsr1)
Qvsrt - Valles Rhyolite, Cerro Santa Rosa Member, pyroclastic flow (Qvsrt)
Qvda4 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, small sanidine phenocrysts (Qvda4)
Qvda3 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, large sanidine phenocrysts (Qvda3)
Qvda2 - Valles Rhyolite, Cerros del Abrigo Member, perlitic lava (Qvda2)
Qvda1 - Valles Rhyolite, Cerros del Abrigo Member, perlitic porphyritic lava (Qvda1)
Qvdmt - Valles Rhyolite, Cerro del Medio Member, pyroclastic flow and pumice fall deposits (Qvdmt)
Qvdm6 - Valles Rhyolite, Cerro del Medio Member, massive devitrified vesicular lava (Qvdm6)
Qvdm5 - Valles Rhyolite, Cerro del Medio Member, upheaved dome of glassy to devitrified lava (Qvdm5)
Qvdm4 - Valles Rhyolite, Cerro del Medio Member, massive aphyric obsidian flow (Qvdm4)
Qvdmn - Valles Rhyolite, Cerro del Medio Member, vesicular flow-banded glassy to devitrified lava (Qvdmn)
Qvdmw - Valles Rhyolite, Cerro del Medio Member, obsidian flow (Qvdmw)
Qvdms - Valles Rhyolite, Cerro del Medio Member, flow-banded sparsely porphyritic lava (Qvdms)
Qrc - Valles Rhyolite, Redondo Creek Member (Qrc)
Qrd2 - Valles Rhyolite, young Rabbit Mountain debris-flow deposits (Qrd2)
Qdc - Valles Rhyolite, Deer Canyon Member (Qdc)
Qdct - Valles Rhyolite, Deer Canyon Member, lithic and crystal rich thin-bedded rhyolitic tuffs (Qdct)
Qcvm - Cerro Toledo Formation, Virgin Mesa Member (Qcvm)
Qcpc - Cerro Toledo Formation, Pueblo Canyon Member (Qcpc)
Qcr - Cerro Toledo Formation, aphyric rhyolite (Qcr)
Qcrt - Cerro Toledo Formation, Valle Toledo Member, Rhyolite tuff (Qcrt)
Qcws - Cerro Toledo Formation, Valle Toledo Member, Warm Springs rhyolite (Qcws)
Qctq - Cerro Toledo Formation, Valle Toledo Member, Cerro Trasquilar rhyolite (Qctq)
Qrd1 - Cerro Toledo Formation, Valle Toledo Member, Old Rabbit Mountain debris-flow deposits (Qrd1)
Qcs - Cerro Toledo Formation, Valle Toledo Member, Sierra de Toledo rhyolite (Qcs)
Qctr - Cerro Toledo Formation, Valle Toledo Member, Turkey Ridge rhyolite (Qctr)
Qcrm - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite (Qcrm)
Qcrmt - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite, bedded tuff (Qcrmt)
Qnd - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte debris avalanche deposit (Qnd)
Qct - Cerro Toledo Formation, Valle Toledo Member (Qct)

Qcep - Cerro Toledo Formation, Valle Toledo Member, East Los Posos rhyolite (Qcep)
Qci - Cerro Toledo Formation, Valle Toledo Member, Indian Point rhyolite (Qci)
Qcnp - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite (Qcnp)
Qcnpt - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite, lithic rich tuff (Qcnpt)
Qcnr - Cerro Toledo Formation, Valle Toledo Member, north caldera rim intrusion (Qcnr)
Qcwp - Cerro Toledo Formation, Valle Toledo Member, West Los Posos rhyolite (Qcwp)
Qbx - Bandelier Tuff, vent and/or hydrothermal breccia (Qbx)
Qbt - Bandelier Tuff, Tshirege Member (Qbt)
Qxbo - Bandelier Tuff, caldera-collapse breccia, Bandelier Tuff, Otowi Member (Qxbo)
Qxt - Bandelier Tuff, caldera-collapse breccia, Tschicoma and Puye Formations (Qxt)
Qxpt - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation dacite tuff (Qxpt)
Qxp - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation andesite and volcaniclastic materials (Qxp)
Qxsf - Bandelier Tuff, caldera-collapse breccia, Santa Fe Group (Qxsf)
Qxr - Bandelier Tuff, caldera-collapse breccia, Ritito Formation (Qxr)
Qxa - Bandelier Tuff, caldera-collapse breccia, Abo Formation and Yeso Group (Qxa)
Qxm - Bandelier Tuff, caldera-collapse breccia, Madera Formation (Qxm)
Qbo - Bandelier Tuff, Otowi Member (Qbo)
Qbog - Bandelier Tuff, Guaje Pumice Bed (Qbog)
Qgo - Bandelier Tuff, older gravels (Qgo)
Qt3 - Terrace gravel, correlative with Santo Domingo Pueblo terraces (Qt3)
Qt2 - Terrace gravel, correlative with Canada terrace of Aby (1997) (Qt2)
Qt1 - Terrace gravel, former courses of Peralta and Cochiti Canyons (Qt1)
Qa3 - Alluvial deposit, boulder gravel and cross-bedded sand (Qa3)
Qp3 - Piedmont alluvial deposit, poorly sorted gravel and sand (Qp3)
Qa2 - Alluvial deposit, cobble and boulder gravel (Qa2)
Qp2 - Piedmont alluvial deposit, gravel, silt and massive sand (Qp2)
Qa1 - Alluvial deposit, cobble and boulder gravel with beds of coarse sand (Qa1)
Qp1 - Piedmont alluvial deposit, gravel (Qp1)
Qba - Basaltic alluvium (Qba)
Qcuc - Andesite of Cochiti volcano, upper unit, cinder deposits (Qcuc)
Qcu - Andesite of Cochiti volcano, upper unit, lava flows (Qcu)
Qlcc - Andesite of Little Cochiti cone, cinder deposits (Qlcc)
Qlc - Andesite of Little Cochiti cone, lava flows (Qlc)
Qd - Dacite of Arroyo Montoso (Qd)
Qcl - Andesite of Cochiti Volcano, lower unit (Qcl)
Qacl - Basaltic andesite of Cochiti Lake (Qacl)

Quaternary and Tertiary Periods

QTtp - Piedmont alluvium (QTtp)
QTcrv - Cerros del Rio volcanic rocks (QTcrv)
QTbt - Basaltic tephra (QTbt)
QTa - Ancha Formation (QTa)
QTslg - Sierra Ladrones Formation (QTslg)
QTc - Cochiti Formation (QTc)
QTsfa - Santa Fe Group, axial channel facies (QTsfa)
QTpf - Puye Formation (QTpf)
QTpt - Puye Formation, ancestral Rio Grande facies (QTpt)

Tertiary Period

Tpl - Puye Formation, lacustrine facies (Tpl)

Tpi - Puye Formation, interbedded thin beds of tephras and/or ignimbrites (Tpi)
Tog - Old fluvial gravel (Tog)
Tbxc - Basalt of Hill 7033, cinder deposits (Tbxc)
Tbx - Basalt of Hill 7033, lava flows (Tbx)
Toc - Andesite of Ortiz Mountain, cinder deposits (Toc)
To - Andesite of Ortiz Mountain, lava flows (To)
Ttoc - Basaltic andesite of Twin Hills, cinder deposits (Ttoc)
Tto - Basaltic andesite of Twin Hills, lava flows (Tto)
Ttdc - Basalt of Hill 7065, cinder deposits (Ttdc)
Ttd - Basalt of Hill 7065, lava flows (Ttd)
Tbtc - Basalt of Tetilla Hole, cinder deposits (Tbtc)
Tbt - Basalt of Tetilla Hole, lava flows (Tbt)
Tcpcd - Basalt of Colorado Peak, cinder deposits (Tcpcd)
Tcb - Basalt of Colorado Peak, lava flows (Tcb)
Tbuc - Basalt of Cañada Ancha, cinder deposits (Tbuc)
Tbu - Basalt of Cañada Ancha, lava flows (Tbu)
Tbzc - Basalt of Hill 6929, cinder deposits (Tbzc)
Tbz - Basalt of Hill 6929, lava flows (Tbz)
Taec - Basaltic andesite of Arroyo Eighteen, cinder deposits (Taec)
Tae - Basaltic andesite of Arroyo Eighteen, lava flows (Tae)
Tclf - Mafic lava flows (Tclf)
Tcba - Benmorite (Tcba)
Tcbc - Cinder deposit (Tcbc)
Tcbm - Mafic hydromagmatic deposits (Tcbm)
Tglp - Gravel of Lookout Park (Tglp)
Ttqc - Tschicoma Formation, upper Quemazon Canyon dacite (Ttqc)
Ttcb - Tschicoma Formation, Caballo Mountain dacite (Ttcb)
Ttpm - Tschicoma Formation, Pajarito Mountain dacite (Ttpm)
Ttcg - Tschicoma Formation, Cerro Grande dacite (Ttcg)
Ttsd - Tschicoma Formation, Sawyer Dome dacite (Ttsd)
Ttcr - Tschicoma Formation, Cerro Rubio dacite (Ttcr)
Ttcd - Tschicoma Formation, dacite intrusion north of Cerro Rubio (Ttcd)
Ttsc - Tschicoma Formation, Santa Clara Canyon dacite (Ttsc)
Ttpd - Tschicoma Formation, Tschicoma Peak area dacite and rhyodacite, undivided (Ttpd)
Ttrc - Tschicoma Formation, Rendija Canyon rhyodacite (Ttrc)
Ttrb - Tschicoma Formation, breccia, white to gray ignimbrite and tephra (Ttrb)
Tti - Tschicoma Formation, small-volume ignimbrites in upper Guaje Canyon, west of the reservoir (Tti)
Tbh - Bearhead Rhyolite (Tbh)
Ttxc - Basaltic andesite of Thirty-One Draw, cinder deposits (Ttxc)
Ttx - Basaltic andesite of Thirty-One Draw, lava flows (Ttx)
Tayc - Basalt of Caja del Rio, cinder deposits (Tayc)
Tay - Basalt of Caja del Rio, lava flows (Tay)
Tmc - Basalt of Montoso Peak, cinder deposits (Tmc)
Tmpb - Basalt of Montoso Peak, lava flows (Tmpb)
Tcpc - Andesite of Cerrita Portillo, cinder deposits (Tcpc)
Tcp - Andesite of Cerrita Portillo, lava flows (Tcp)
Tbclc - Basaltic andesite of Arroyo Calabasas, cinder deposits (Tbclc)
Tbclf - Basaltic andesite of Arroyo Calabasas, lava flows (Tbclf)
Tb - Basalt of La Bajada Rim (Tb)
Tbsc - Basalt of Tsinat Mesa, cinder deposits (Tbsc)
Tbs - Basalt of Tsinat Mesa, lava flows (Tbs)
Tbcc - Basaltic andesite of Cerro Micho, cinder deposits (Tbcc)
Tbc - Basaltic andesite of Cerro Micho, lava flows (Tbc)

Tbhm - Hydromagmatic deposits (Tbhm)
Tbcl - Basalt of Cochiti Lake (Tbcl)
Tcac - Andesite of Colorado Peak, cinder deposits (Tcac)
Tca - Andesite of Colorado Peak, lava flows (Tca)
Tat - Andesite of Tetilla Peak (Tat)
Tas - Andesite of Sanchez Canyon (Tas)
Tcmc - Andesite of Cerro Micho, cinder deposits (Tcmc)
Tcm - Andesite of Cerro Micho, lava flows (Tcm)
Taba - Andesite and basaltic andesite, undivided (Taba)
Tbi - Bearhead Rhyolite, intrusions (Tbi)
Tkpt - Bearhead Rhyolite, Peralta Tuff Member (Tkpt)
Tsf - Santa Fe Group, undivided (Tsf)
Tstv - Volcaniclastic sediments (Tstv)
Tscv - Chamita Formation, lower Vallito Member (Tscv)
Tscu - Chamita Formation, Hernandez Member (Tscu)
Tcar - Chamita Formation, axial river sediment (Tcar)
Tccu - Chamita Formation, Cuarteles Member (Tccu)
Tccuf - Chamita Formation, Cuarteles Member, fine-grained, distal sediment (Tccuf)
Tstb - Tesuque Formation, basalt flow (Tstb)
Tstc - Tesuque Formation, Chama-El Rito Member (Tstc)
Ttcu - Tesuque Formation, Cuarteles Member (Ttcu)
Ttcuf - Tesuque Formation, Cuarteles Member, fine-grained, distal sediment (Ttcuf)
Tsfb - Basalt flows and cinders (Tsfb)
Tscc - Cerro Conejo Formation (Tscc)
Tqv - Quartz veins (Tqv)
Tghd - La Grulla Formation, hornblende dacite and rhyodacite (Tghd)
Tgbhd - La Grulla Formation, porphyritic biotite, hornblende rhyodacite (Tgbhd)
Tgb - La Grulla Formation, olivine basalt (Tgb)
Tga - La Grulla Formation, porphyritic andesite and dacite, undivided (Tga)
Tpgd - Dacite outcrop in Guaje Canyon (Tpgd)
Tpv - Paliza Canyon Formation, volcaniclastic member, conglomerate sandstone (Tpv)
Tpvs - Paliza Canyon Formation, volcaniclastic member, sandstone (Tpvs)
Tpb - Paliza Canyon Formation, olivine basalt and basaltic andesite, undivided (Tpb)
Tpa - Paliza Canyon Formation, Two-pyroxene andesite, undivided (Tpa)
Tpbhd - Paliza Canyon Formation, porphyritic biotite, hornblende dacite (Tpbhd)
Tpmc - Paliza Canyon Formation, trachyandesite of Mesita Cocida (Tpmc)
Tpai - Paliza Canyon Formation, andesite dikes that may be the source of the trachyandesite of Mesita Cocida (Tpai)
Thb - Paliza Canyon Formation, hydrothermal breccia (Thb)
Tpdt - Paliza Canyon Formation, porphyritic dacite tuff (Tpdt)
Tpd - Paliza Canyon Formation, aphyric dacite (Tpd)
Tpbd - Paliza Canyon Formation, porphyritic biotite dacite (Tpbd)
Tpbb - Paliza Canyon Formation, basalt of Bodega Butte (Tpbb)
Tpbbs - Paliza Canyon Formation, scoria facies of basalt of Bodega Butte (Tpbbs)
Tpbt - Paliza Canyon Formation, basalt, hydromagmatic tephra (Tpbt)
Tpbi - Paliza Canyon Formation, basalt, Basaltic dikes (Tpbi)
Tppa - Paliza Canyon Formation, porphyritic andesite (Tppa)
Tphd - Paliza Canyon Formation, porphyritic hornblende dacite (Tphd)
Tpha - Paliza Canyon Formation, hornblende andesite (Tpha)
Tm - Paliza Canyon Formation, Monzonite dikes and stocks (Tm)
Tct - Canovas Canyon Rhyolite lavas (Tct)
Tcct - Canovas Canyon Rhyolite (Tcct)
Tcc - Canovas Canyon Rhyolite, domes, flows, and intrusions (Tcc)

Tpoa - Olivine andesite (Tpoa)
Tpcm - Basalt of Chamisa Mesa (Tpcm)
Tbm - Bland monzonite (Tbm)
Tlb - Polvadera Group volcanic rocks (Tlb)
Ta - Abiquiu Formation (Ta)
Tgs - Galisteo Formation (Tgs)

Triassic Period

TRcu - Upper Chinle Group, undivided (TRcu)
TRcs - Shinarump Formation (TRcs)
TRm - Moenkopi Formation (TRm)

Permian Period

Pg - Glorieta Sandstone (Pg)
Py - Yeso Group (Py)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qaf - Artificial fill (latest Holocene)

af - Artificial fill (latest Holocene)
Rock and earth fill of Cochiti Dam and associated structures. *GRI Source Map ID 7228* (SIM 3194).

af - Artificial fill (latest Holocene)
Uncompacted mine tailings and storage piles composed of dark red (10R about 3/6), cinder, spatter, and agglutinate excavated from basaltic pyroclastic deposits at Cerrito Pelado, near the southeastern corner of the map area.Locally may include in-place pyroclastic depositis. Estimated thickness less than 15 m. *GRI Source Map ID 75593* (SIM 3179).

f - Fill (Holocene)
Recent sand, gravel, and other compacted construction materials beneath roadways. Thickness probably 3–8 m. Present beneath State Routes 502 and 30, but mapped only at their intersection. *GRI Source Map ID 6547* (MF 2419).

Qdi - Disturbed areas (Holocene)

Qdi - Disturbed areas (Holocene)
Anthropogenically disturbed areas consisting of underlying rock units at each site; not shown in correlation chart; maximum thickness less than 5m. *GRI Source Map ID 75592* (GM 79).

Qdi - Disturbed Areas (Holocene)
Anthropogenically disturbed areas; consists of underlying rock units at each area; unit mapped only where extensive at pumice mines and well pads; not shown in correlation chart; maximum thickness more than 10 m but usually less than 3m. *GRI Source Map ID 7226* (OF-GM 111).

Qdi - Disturbed Mesa Top (Holocene)
Highly disturbed mesa top deposits of man-made origin; usually consists of a mixture of older alluvium, Bandelier Tuff rubble, mesa top soil, and imported fill; latter contains conspicuous clasts of Precambrian lithologies; unit mapped only where extensive at larger technical areas of Los Alamos National Laboratory (LANL); maximum thickness more than 2 m but usually less than 1 m. *GRI Source Map ID 7224* (OF-GM 42).

Qtp - Piedmont alluvium (Holocene)

Poorly sorted cobble to boulder gravel, cross- to planar-bedded sand, boulder-rich debris-flow deposits, and eolian sediment exposed along active channels of large drainages such as Guaje and Santa Clara Canyons and their major tributaries and beneath adjacent low surfaces. Deposits generally sand-rich west of and above exposures of the Puye Formation. Exposed thickness generally less than 4 m, but as much as 10 m in borrow pits along lower Bayo and Guaje Canyons. Generally overlies Santa Fe Group, Puye Formation, or Quaternary units; locally inset against or gradational with alluvial fan deposits or older piedmont alluvium. In Bayo Canyon,14C ages from buried charcoal layers 3–6 m below the modern channel range from 4930 to 4280 yr B.P. (Riihimaki and Dethier, 1998). *GRI Source Map ID 6547* (MF 2419).

Qal - Alluvium (Holocene to Pleistocene)

Qal - Alluvium (Quaternary)
Deposits of gravel, sand and silt in canyon bottoms; locally includes stream terraces and canyon wall colluvium; mostly Holocene in age; maximum thickness exceeds 15 m. *GRI Source Map ID 7225* (OF-GM 112).

Qa - Alluvium (Holocene)
Cross- to planar-bedded sand, pebbly sand, and thin beds of silty sand exposed along the Rio Grande, along active channels of tributary arroyos, beneath adjacent low (< 3 m) terraces and on low-gradient alluvial fans at the mouths of Sanchez and Medio Canyons. Beds generally less than 0.5 m thick. Includes some late Pleistocene deposits in upland areas northeast of the Town of Cochiti Lake. Actual thickness is probably greater than 10 m along the Rio Grande. Soils thin (< 0.5 m) ranging from A/C profiles to profiles with Bw and (or) Bk horizons with Stage II carbonate morphology on low terraces. Exposed thickness 2–4 m, base not exposed. *GRI Source Map ID 7228* (SIM 3194).

Qal - Alluvium (mostly Holocene)
Deposits of sand, gravel, and silt in main valley bottoms; maximum thickness may exceed 15 m. *GRI Source Map ID 75592* (GM 79).

Qal - Alluvium (Holocene to Pleistocene)
Silt, sand and gravel deposited in modern drainages; may include terrace deposits. Streams draining the Sierra de Los Valles are particularly laden with sand and gravel of the rhyodacite or dacite derived from the Tschicoma Formation; stream deposits within the Pajarito Plateau contain abundant clasts and phenocryst grains of the Bandelier Tuff. Holocene to Pleistocene in age (Phillips et al., 1998; Reneau, 2000) with a maximum thickness of ~ 5 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qva - Valley-fill allluvium (upper Pleistocene to Holocene)
Very fine- to medium-grained sand and clayey-silty sand interbedded with subordinate gravelly beds; unit occupies the floors of valleys, where it commonly has a late Holocene terrace tread incised by a modern arroyo or channel. The modern channel is included in this unit and is generally composed of gravelly sand. The tread height of the late Holocene terrace relative to the modern arroyo is highly variable. Color of sediment varies according to texture and source area. Clayey-silty very fine- to medium-grained sand ranges from light yellowish brown (10YR 6/4), pale brown (10YR 6/3), brown (10YR 5/3), light brown (7.5YR 6/3), yellowish-brown (10YR 5/4), or very-pale-brown (10YR 7/4). Medium- to very coarse-grained sand beds are typically light brown to pink (7.5YR 6-7/3-4). Clay-silt or clayey-silty sand is generally massive or in very thin to thin beds. Sandy and gravelly sediment occurs in very thin to medium, tabular or lenticular beds. These beds contain internal planar- or cross-laminations. Gravel commonly occupies less than 50% of the total sediment volume; larger drainages have more gravel than smaller drainages. Gravel is clast- or matrix-supported and dominated by pebbles. Cobbles and boulders are abundant only near crystalline basement or in the modern channel of the Rio Grande. Gravel clasts are mostly granite to granitic gneiss (with very minor quartzite, schist, gneiss, and amphibolite). Cobbles and very coarse pebbles are rounded to subrounded whereas finer gravel are subrounded to angular. Sand is very fine- to very coarse-grained, poorly to well sorted, subangular to subrounded, and arkosic. Clayey sediment is typically hard whereas sandy sediment is loose. The top soil has a calcic horizon with stage I morphology (10-50 cm thick). Buried soils have calcic horizons with stage I to II pedogenic carbonate morphology (10-50 cm thick) and may have soil horizons (5-15 cm thick) with clay accumulation. Buried soils locally define 1 to 3 (possibly more) alluvial allostratigraphic units. An upper Pleistocene to Holocene age is supported by the relatively weak soil development of the top soil. Radiocarbon ages obtained from buried charcoal in this unit range from of 2,230 +/- 250 radiocarbon years (Miller and Wendorf, 1958) to 4160 +/- 40 yr (Koning and Hallett, 2000), but the soil-bounded allostratigraphic units suggest that upper Pleistocene sediment is locally preserved. 1 to 25 m in thickness. *GRI Source Map ID 75477* (OFR 531).

Qal - Alluvium (Quaternary)
Deposits of gravel, sand and silt in canyon bottoms; locally includes stream terraces and canyon wall colluvium; mostly Holocene in age; maximum thickness exceeds 15 m. *GRI Source Map ID 7226* (OF-GM 111).

Qal - Alluvium deposited by active streams (Upper Pleistocene? to Holocene)
Poorly sorted gravelly sand and sandy gravel deposited in channels and minor floodplain areas of ephemeral streams and arroyos. Beds of eolian fine sand up to 0.5 m thick are locally present, and colluvium is present near valley margins. Total thickness is unknown but may be as much as 10-30 m. *GRI Source Map ID 7218* (OF-GM 85).

Qal - Alluvium (Holocene)
Deposits of gravel, sand and silt in canyon bottoms; locally includes stream terraces; mostly Holocene in age based on 14C dates, although El Cajete pumice encountered by some drill holes indicates that some alluvium exceeds 50-60 ka (e.g., Reneau and McDonald, 1996; Reneau et al., 1996; Reneau, 2000; Gardner et al., 2001); maximum thickness exceeds 15 m. *GRI Source Map ID 7224* (OF-GM 42).

Qal - Alluvium (Late Pleistocene to Holocene)
Alluvial deposits in modern drainage bottoms. Deposits include conglomerates, sands, and silts. Holocene terrace deposits less than 1 meter above drainage bottoms are included. Maximum thickness can exceed 5 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qal - Channel and flood-plain deposits of the Rio Grande and tributary rivers (Holocene)
Cross- to planar-bedded sand, pebbly sand, pebble to cobble gravel, and thin beds of silty sand exposed along the Rio Grande, Rio Pojoaque (immediately east of Rio Grande), and beneath adjacent low terraces (<4 m above river). Beds generally less than 0.5 m thick. Exposed thickness 2–4 m in the southeastern part of map area. Actual thickness probably more than 10 m along the Rio Grande. Base not exposed. Soils thin (<0.5 m) with A/C or Bw horizons (Birkeland, 1999) on low terraces. *GRI Source Map ID 6547* (MF 2419).

Qfa - Alluvial fan deposits (Holocene to middle Pleistocene)

Qaf - Alluvial fans (Quaternary)
Fan-shaped deposits of coarse to fine gravel and sand at the mouths of valleys and in the Valle Grande; some fan deposits may be difficult to distinguish from older alluvial fans; deposits in the Valle Grande are younger than the 50 to 60 kyr El Cajete pumice; maximum exposed thickness about 15 m. *GRI Source Map ID 7225* (OF-GM 112).

Qaf - Fan alluvium (Holocene to middle Pleistocene)
Cross-bedded, poorly sorted cobble to boulder gravel and poorly sorted, matrix-rich debris-flow deposits. Older deposits are preserved as remnants 5–15 m above active alluvial fans on slopes from 4° to 10°. Includes eolian deposits and local areas of ~55 ka El Cajete tephra along La Bajada fault escarpment in the southeast part of map area. Soils within deposit are poorly exposed, but locally thicker than 1 m, with Stage III or weak Stage IV carbonate morphology. Thickness probably 4–20 m; most contacts obscured by colluvium. *GRI Source Map ID 7228* (SIM 3194).

Qaf - Alluvial fans (late Holocene to late Pleistocene)
Typically fan-shaped deposits of coarse to fine gravel and sand, silt, and clay within and at the mouths of valleys and inside north and east caldera margins; some fan deposits (Qafu) are difficult to distinguish from older alluvial fans (described below); maximum exposed thickness about 15 m. *GRI Source Map ID 75592* (GM 79).

Qfa - Alluvial fan deposits (middle Pleistocene to Holocene)
Gravelly stream-flow and debris-flow deposits in fan-shaped lobes at the mouths of incised tributary arroyos in Santa Fe River Canyon, White Rock Canyon, and along the Rio Galisteo; also found at the base of the La Bajada escarpment. Sediment is gravel or gravelly sand, with local interbeds of clay, silt, and clayey sand; sand is subangular to subrounded. Gravel ranges from pebbles to boulders (mostly pebbles and cobbles); clasts are angular to rounded, as large as 2 m, and composed of basalt (local granite and quartzite); granite dominates in alluvial fans near Santa Fe. Color varies according to changes in the parent material, but light yellowish brown to light brown (7.5-10YR 6/4) is common. Poorly to well sorted and unconsolidated. Stream-flow sandy gravel is generally clast-supported and in lenticular to concave-up, ribbon-shaped beds that are very thin to thin. Silt, clay,or sand may be massive or tabular and thin to medium-bedded. Debris-flow sediment consist of very poorly sorted and very poorly stratified boulders to granules supported in a sandy matrix.
Unit interfingers with Qay and alluvium of La Majada Mesa. Deposits locally overlain by and interbedded with unit Qse. A middle Pleistocene to Holocene age is assigned based on the unit's relatively low topographic position in the landscape. Deposits range in thickness from 2 to 30 m [Description taken in part from Sawyer et al., 2002]. *GRI Source Map ID 75477* (OFR 531).

Qaf - Alluvial fans (Quaternary)
Fan-shaped deposits of coarse to fine gravel and sand at the mouths of valleys and in the Valle Grande; maximum exposed thickness about 15 m. *GRI Source Map ID 7226* (OF-GM 111).

Qaf - Alluvial fans (Holocene and Pleistocene)
Fan-shaped deposits of coarse to fine gravel and sand at the mouths of valleys, or older, coalesced fan deposits along the Pajarito fault zone; latter deposits partially Holocene in age as determined from 14C dates (e.g., Gardner et al., 2001); other deposits partially overlain by El Cajete pumice; may be difficult to distinguish from older alluvium; maximum exposed thickness about 15 m. *GRI Source Map ID 7224* (OF-GM 42).

Qaf - Tributary alluvial fan deposits (Holocene to upper Pleistocene)
Cross-bedded, poorly sorted cobble to boulder gravel; poorly sorted, boulder-rich debris-flow deposits; and local silt- and clay-rich fine sand exposed in active alluvial fans on slopes of 5–15° and as remnants 5–10 m above modern fans. Clasts rich in dacite and locally Bandelier Tuff. Thickness probably 4–10 m; most contacts obscured by colluvium. Overlies rocks of the Santa Fe Group and the Puye Formation. Soils poorly exposed, but locally contain Stage II carbonate (Birkeland, 1999) in decimeter-thick horizons. In lower Guaje Canyon, 14C ages from buried charcoal layers in the upper 5 m of deposits range from 3450 to 2010 yr B.P. (Riihimaki and Dethier, 1998). *GRI Source Map ID 6547* (MF 2419).

Qafu - Alluvial fans, difficult to distinguish from older fans (late Holocene to late Pleistocene)

Qafu - Alluvial fans (late Holocene to late Pleistocene)
Typically fan-shaped deposits of coarse to fine gravel and sand, silt, and clay within and at the mouths of valleys and inside north and east caldera margins; some fan deposits are difficult to distinguish from older alluvial fans; maximum exposed thickness about 15 m. *GRI Source Map ID 75592* (GM 79).

Qafp - Piedmont alluvial fan deposits (Holocene to upper Pleistocene(?))
Crossbedded sand, poorly to moderately well sorted pebble gravel, eolian fine sand and silt, and local, boulder-rich debris-flow deposits preserved in coalescent alluvial fans proximal to the Rio Grande meander belt. Clasts mainly dacite. Surfaces locally as much as 8 m above modern channels. Thickness probably 4 to more than 20 m; most contacts obscured by colluvium. Overlies rocks of the Santa Fe Group. Surface soils weakly developed; buried soils locally expose Bt and Btk horizons

containing Stage II carbonate morphology (Birkeland, 1999). 14C ages from buried charcoal layers in the upper 5 m of deposits in the southeast map area range from 5020 to 2020 yr B.P. (Riihimaki and Dethier, 1998). *GRI Source Map ID 6547* (MF 2419).

Qa5 - Alluvial deposit, beds of sand (Holocene to late Pleistocene)

Cross-to planar-bedded sand and pebbly sand, and thin beds of silty sand beneath narrow terraces 3–10 m above the Rio Grande. Beds generally <0.5 m thick. Most extensive deposits located 1 km south of Alamo Canyon. Soils thin (<0.5 m) ranging from A/C profiles to profiles with Bw and (or) Bk horizons with Stage II carbonate morphology. Exposed thickness 3–10 m, base not exposed. *GRI Source Map ID 7228* (SIM 3194).

Qp5 - Piedmont alluvial deposit, sand and gravel (Holocene to late Pleistocene)

Qp5 - Piedmont alluvial deposit 5 (Holocene to late Pleistocene)
Cross-to planar-bedded sand and pebbly sand and poorly sorted gravel. Clasts predominantly andesite and silicic tuff derived from the Jemez Mountains to the west; matrix rich in lithic fragments and quartz. Deposits 0.5– 4.0 m thick are exposed beneath terraces 3–10 m above Rio Chiquito and adjacent tributaries graded to the Rio Grande. Beds generally <0.5 m thick. Soils are thin (<0.5 m) ranging from A/C profiles to profiles with Bw and (or) Bk horizons with Stage II carbonate. Exposed thickness 3–10 m, base not exposed. *GRI Source Map ID 7228* (SIM 3194).

Qtp5 - Piedmont alluvium (Holocene to upper Pleistocene(?))
Cross-bedded to planarbedded sand and pebbly sand and poorly sorted gravel beneath terraces adjacent to active channels of major drainages such as Santa Clara, Guaje, and Pueblo Canyons and their tributaries. Clasts predominantly dacite and other rock types derived from the Puye Formation and recycled Tschicoma Formation; matrix rich in subangular lithic fragments (mainly dacite) and quartzite. Deposits 0.5–5.0 m thick exposed beneath terraces 3–8 m above modern channels. Beds generally less than 0.5 m thick. Exposed thickness 3–8 m. Base not exposed. Soils thin (<0.5 m) with multiple buried A/C and Bw horizons; locally contains Stage II carbonate (Birkeland, 1999). *GRI Source Map ID 6547* (MF 2419).

Qpa - Alluvial and eolian deposit (Holocene to Pleistocene)

Qsw - Sheetwash deposits (Holocene and early Pleistocene)
Sand, fine sand, silt, and one or more buried soils capping mesas isolated from major arroyos. Locally includes eolian deposits, some reworked. Most deposits include primary and reworked El Cajete tephra and admixed basaltic colluvium. Overlies basalt and andesite flows or older alluvial deposits. Overlain by eroded late Pleistocene or Holocene fluvial and eolian deposits. Soils within unit are 1.0 to > 2.0 m thick and contain buried Bt horizons and local Stage IV carbonate morphology and are locally brecciated. Thickness 2–8 m. *GRI Source Map ID 7228* (SIM 3194).

Qes - Eolian and sheet wash deposits (Holocene to Pleistocene)
Tan to brown silt-to clay- rich soil that develops primarily on Cerro Toledo interval on the east side of the map area. Soil material is transported in by the wind, but is reworked by slope wash. Holocene to Pleistocene in age with an average thickness of ~ 1 meter. *GRI Source Map ID 6633* (OF-GM 55).

Qsw - Sheetwash deposits (Holocene to middle? Pleistocene)
Slightly pebbly to pebbly and cobbly, slightly silty to silty, very fine to medium sand. The matrix is slightly to moderately plastic. Some of the silt- to fine sand-size fraction in these deposits may be of

eolian origin and have been transported by strong southwesterly winds that deflated sediment from former sparsely vegetated or actively aggrading alluvial deposits. Some of the silt- and clay-size fraction in Qsw may have been derived from more distant sources (Shroba and Thompson, 1998). Sediments in Qsw were deposited chiefly by unchannelized surface flow and, possibly in part, by gravity-driven slope processes. Unit Qsw locally contains rare fragments of reworked pumice from the 1.61 Ma Guaje(?) Pumice Bed of the Otowi Member of the Bandelier Tuff (Bailey and others, 1969; Izett and Obradovich, 1994) and possibly pumice (Qvec) from younger eruptions in the nearby Jemez Mountains, about 25 km northwest of the map area (fig. 1). The unit also locally includes small deposits of undivided alluvium and colluvium (Qac) and basaltic alluvium (Qba). Although loess locally mantles lava flows about 50–60 ka in the Valles caldera (Wolff and others, 1996) (fig. 1) and rock-glacier deposits about 10–14 ka near Lake Peak in the Sangre de Christo Range (Shroba, 1977, 1987), loess deposits were not observed within or on Qsw. Surface soils formed in Qsw in the adjacent Agua Fria and Tetilla Peak quadrangles (Shroba and others, 2006; Sawyer and others, 2002) locally have Bw, Bt/Bk, or Btk/K horizon morphology depending in part on the age of the deposit. Bt and Btk horizons have thin clay films on ped faces. Bt horizons are 20–70 cm thick; Btk horizons are 10–45 cm thick and have stage I–II carbonate morphology. Bk horizons are as much as 80 cm thick and have stage I to II carbonate morphology. K horizons are as much as 75 cm thick and have stage III carbonate morphology. These properties suggest that some of the more strongly developed soils are formed in deposits that may be about 120–160 ka (Shroba and Birkeland, 1983; Nelson and Shroba, 1998; Birkeland and others, 2003). Although undifferentiated, younger deposits locally overlie older deposits of Qsw. Older sheetwash deposits are locally greater than 2 m thick and have upper surfaces marked by buried Bkb, Btkb, or Kb horizons greater than 30 cm thick. Presence of surface and buried soils formed on and in Qsw indicate periodic deposition followed by surface stability and soil development. The last major episode of deposition may have been associated with enhanced summer rainfall during the early Holocene (Reneau and others, 1996b). Low-lying areas of Qsw are susceptible to sheet flooding due to unconfined overland flow, and locally to stream flooding and gullying. Disturbed surface of Qsw may be susceptible to minor wind erosion. Exposed thickness 1.5–4.5 m; possibly as much as 10 m. *GRI Source Map ID 75593* (SIM 3179).

Qse - Sheetflood deposits and minor eolian sediment (upper Pleistocene to Holocene)
Yellowish brown (10YR 5/4) to light yellowish brown (10YR 6/4), pebbly and silty-clayey sand deposited by sheetflooding; the fine sediment was probably derived chiefly from eolian material that was later reworked and deposited by unconfined surface flow. Pebbles are commonly subangular to subrounded and variably consist of volcanic rocks, granite, or sandstone (depending on location and source area). Sand is very fine- to very coarse-grained (mostly very fine- to medium-grained), quartz-rich, and vaguely bedded (mostly very thin-bedded). Sediment is poorly sorted, loose, and slightly to moderately plastic. This unit was not differentiated where it overlies Santa Fe Group sediment. Small deposits of El Cajete pumice are locally present in the northwestern part of the Montoso Peak quadrangle to the north (Thompson et al., in preparation). Surface soil generally has a weak argillic horizon underlain by a calcic horizon with stage I to II carbonate morphology. Buried soils on the Caja del Rio Plateau have calcic horizon(s) with stage III carbonate morphology locally overlain by eroded argillic horizons (Sawyer et al., 2002). These soils indicate periodic deposition during the Holocene and upper Pleistocene, followed by surface stability and soil development. Unit may include small deposits of alluvium, colluvium, or eolian sand. Mostly 1-2 m thick, with a possible maximum thickness of 5 m. [Description taken in part from Sawyer et al. (2002) and Shroba et al. (2005)].. *GRI Source Map ID 75477* (OFR 531).

Qe - Eolian sand and silt (Upper Pleistocene to Holocene)
Massive fine sand and coarse silt forming a 0.5-3 m thick deposit, primarily on top of the ancient geomorphic surface that is underlain by the gravel of Lookout Park. *GRI Source Map ID 7218* (OF-GM 85).

Qe - Upland alluvium, colluvium, and eolian deposits, undivided (Holocene to upper Pleistocene (?))

Poorly sorted alluvial gravel, sand, and silt interbedded with fine-grained, well-sorted eolian sand and silt. May be locally interbedded with El Cajete ash (Qvec). Commonly found in flat, broad areas adjacent to major drainages on the flat tops of ridges and divides in the southwest portion of the quadrangle. Generally <1 m thick. *GRI Source Map ID 6630* (OF-GM 74).

Qpa - Alluvial and eolian deposits (Holocene to Pleistocene)
Sand, fine sand, silt, and one or more buried soils capping mesas, broad interfluves, and adjacent low-angle slopes 60 to more than 110 m above major drainages. Beds less than 0.5 m thick and discontinuous. Matrix locally rich in quartz and sanidine derived from Bandelier Tuff. Most deposits include dacitic cobble to boulder gravel derived from alluvial deposits of the Cerro Toledo interval or from the Puye Formation. Deposits generally 2–8 m thick. Overlies lower part of Bandelier Tuff, Puye Formation, or older piedmont deposits. Soils are polygenetic, 0.5–1.0 m thick, and contain multiple buried Bt horizons and local Stage IV carbonate (Birkeland, 1999). *GRI Source Map ID 6547* (MF 2419).

Qls - Landslides (Holocene to Pleistocene)

Qls - Landslides (Quaternary)
Unsorted debris that has moved chaotically down steep slopes, or slumps or block slides partially to completely intact, that have moved down slope; slumps and block slides usually display some rotation relative to their failure plane; thickness varies considerably depending on the size and nature of the landslide. *GRI Source Map ID 7225* (OF-GM 112).

Qls - Landslide deposit (Holocene to early Pleistocene)
Massive gravity slide deposits mantled by basaltic colluvium, mainly exposed along the steep walls of White Rock Canyon, along the La Bajada fault scarp and in the Jemez Mountains. Deposits consist of slump blocks with coherent internal stratigraphy near canyon rims and progressively deformed slumps and debris flows closer to the Rio Grande. Stratigraphic dips in the slump blocks range from 10° to 30° toward head scarps. Failures mainly occurred along steeply dipping planes rooted in the Santa Fe Group, and in hydromagmatic deposits and other altered volcanic rock. Slide material overlies rocks of the Santa Fe Group at most sites. Deposit morphology and inclusion of upper Bandelier Tuff in some deposits suggests that slides were active in early Pleistocene time, but that many stabilized in middle to late Pleistocene time. Carbonate morphology is Stage IV at some sites, and Stage III carbonate morphology and buried Btk horizons are present in most exposures. Soils are generally 0.8 to 1.4 m thick. Most slides are inactive, but lake drawdown after high levels in the mid-1980s reactivated several major slides along the western margin of Cochiti Lake. El Cajete tephra (~55 ka) overlies landslide deposits near Cochiti Lake and along the La Bajada escarpment. *GRI Source Map ID 7228* (SIM 3194).

Qls - Landslides (late Holocene to late Pleistocene)
Poorly sorted debris that has moved chaotically down steep slopes; includes slumps or block slides that are partially to completely intact; thickness varies considerably depending on the size and nature of the landslide. *GRI Source Map ID 75592* (GM 79).

Qls - Landslides (Holocene to Pleistocene)
Two types: slump or block slides that remain nearly intact after detaching from a steep slope or cliff, or unsorted, chaotic debris emplaced during a chaotic detachment event from a steep slope or cliff. The latter deposits are typically fan-shaped on the valley floor. Holocene to Pleistocene in age of highly variable thicknesses. *GRI Source Map ID 6633* (OF-GM 55).

Qls - Landslides and other large-scale mass wasting deposits (lower Pleistocene to Holocene)
Massive slumps on slopes below mesa tops composed of basalt or, less commonly, Bandelier Tuff. Unit mainly exposed along the La Bajada escarpment, White Rock Canyon, north of Chaquehui Canyon, and along Cañada Ancha. Slump blocks commonly contain coherent internal stratigraphy in their upper parts

but become progressively more deformed in their lower parts. The lower parts include debris slide, debris slump, and debris flows deposits (as defined by Varnes, 1978) and are characterized by poorly to very poorly sorted and non-stratified rock debris. Dips in massive slump blocks range from 8° to 70° toward head scarps. Surface topography is typically hummocky. Many of the landslide deposits exhibit lobate toes and crescentic headwall scarps. Slide material at most sites overlies Santa Fe Group strata. Limited areas of autochthonous rocks are included in areas mapped as Qls. Slope failures probably initiate in weakly to moderately consolidated sediments beneath the hard strata and propagate upward into the overlyingcliff-forming units. Most slides are inactive. At several locations undisturbed late Pliocene deposits lie stratigraphically above landslide deposits (Section H of Dethier, 1997). Morphology of most failures and inclusion of Bandelier Tuff in some suggest that slides were active in early to middle Pleistocene time but that many became stable in the middle to late Pleistocene (Dethier, 1997). El Cajete tephra (~50-60 ka; Reneau et al., 1996) lies on landslide deposits south of the White Rock area. Some of the older landslide deposits have thick calcic soil horizons with stage III carbonate morphology, with stage IV present at some localities. Soils are generally 0.8-1.4 m (2.5-4.5 ft) thick. Landslide deposits may be prone to continued movement or reactivation due to natural as well as human-induced processes. Maximum thickness possibly 100 m. [Description from Dethier (1997) and Sawyer et al. (2002)]. *GRI Source Map ID 75477* (OFR 531).

Qls - Landslides (Quaternary)
Unsorted debris that has moved chaotically down steep slopes, or slumps or block slides partially to completely intact, that have moved down slope; slumps and block slides usually display some rotation relative to their failure plane; thickness varies considerably depending on the size and nature of the landslide. *GRI Source Map ID 7226* (OF-GM 111).

Qls - Landslides (Upper Pleistocene to Holocene)
Poorly sorted debris that has moved down steep slopes chaotically or as a series of blocks. *GRI Source Map ID 7218* (OF-GM 85).

Qls - Landslides (Holocene and Pleistocene)
Unsorted debris that has moved chaotically down steep slopes, or slumps or block slides that have moved down slope partially to completely intact; slumps and block slides usually display some rotation relative to their failure plane; older slides may be overlain by El Cajete pumice or by older alluvium; thickness varies considerably depending on the size and nature of the landslide. *GRI Source Map ID 7224* (OF-GM 42).

Qls - Landslides (Pleistocene to Holocene)
Slump or block slides that remain nearly intact after detaching from a steep slope or cliff, or unsorted, chaotic debris emplaced during a single detachment event from a steep slope or cliff. Fan-shaped deposits occur where debris spread out on valley floor. Thicknesses highly variable. *GRI Source Map ID 6630* (OF-GM 74).

Qls - Landslide deposits (Holocene to middle(?) Pleistocene)
Slump complexes that consist of broken caprock of Bandelier Tuff or basalt, mantled by colluvium, mainly exposed between Los Alamos and Chupaderos Canyons and along the Rio Grande near the mouth of Los Alamos Canyon. Deposits contain massive slump blocks with coherent internal stratigraphy near source areas, and are progressively more deformed further from head scarps. Dips in slump blocks range from 10° to 50° toward head scarps. Slumps have two general origins: those involving the upper part of Bandelier Tuff and exposed north of Los Alamos Canyon failed along sub-horizontal planes in lacustrine clays (principally Tpl) of the Puye Formation. Slides south of Los Alamos Canyon and close to the Rio Grande are capped by basalt and have failure plane(s) in the Santa Fe Group. Slide material overlies the Puye Formation or Santa Fe Group at most sites. Failures probably started in middle Pleistocene time as the Rio Grande and large tributaries incised rapidly through Pliocene and Miocene rocks (Reneau and Dethier, 1996). Most slides are inactive or moving only slowly.

Soils are generally 0.8–1.4 m thick. Carbonate morphology (Birkeland, 1999) in colluvium overlying landslides is Stage IV at some sites, and Stage III carbonate and buried Btk horizons are present at several exposures. *GRI Source Map ID 6547* (MF 2419).

Qc - Colluvium (Holocene to Pleistocene)

Qc - Colluvium (Quaternary)
Poorly sorted slope wash and mass wasting deposits from local sources; mapped only where extensive or where covering critical contacts or fault relations; mostly Holocene and Pleistocene in age; thickness can locally exceed 10 m. *GRI Source Map ID 7225* (OF-GM 112).

Qc - Colluvium (Holocene to middle Pleistocene)
Rockfall, debris-flow, and poorly sorted alluvial deposits at the base of cliffs, particularly along White Rock Canyon and major tributaries such as Capulin Canyon. Texture and clast lithology is variable. Deposits include ~55 ka El Cajete tephra in many areas. Overlies Bandelier Tuff in the northwest part of map area and volcanic rocks and landslides elsewhere. Northwest of the Pajarito fault zone, Goff and others (1990) showed colluvial deposits "...only where extensive or where covering critical contacts." Surface soils are thin (<0.5 m) and weakly developed at most locations, but lenses of El Cajete tephra, buried soils with strong Bt horizons (west of the Rio Grande) or K-horizons (in White Rock Canyon) demonstrate that many deposits are locally older than late Pleistocene. Thickness generally 4–10 m, but locally exceeds 25 m along White Rock Canyon. *GRI Source Map ID 7228* (SIM 3194).

Qc - Colluvium (mostly Holocene)
Poorly sorted slope wash and mass wasting deposits from local sources; mapped only where extensive or where covering critical relations; thickness locally exceeds 15 m. *GRI Source Map ID 75592* (GM 79).

Qc - Colluvium (Holocene to Pleistocene)
Talus debris that typically form wedge-shaped deposits adjacent to cliffs (in particular the Tshirege Member of the Bandelier Tuff, Qcbt). Debris is unsorted to poorly-sorted, often obscuring faults and/or contacts between rock units. Although abundant, these deposits were mapped in only a few locations, particularly on north facing slopes. Holocene to Pleistocene in age with a maximum thickness of ~ 15 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qc - Colluvium, undivided (Holocene to middle? Pleistocene)
Deposits of unsorted and non-stratified, mostly matrix-supported, sandy sediment and rock debris on and near steep slopes. Deposits range in size from pebbly silty sand to cobbly and bouldery rubble with a sandy matrix. Unit Qc consists chiefly of soil-creep, debris-flow, and rock-fall deposits, as defined by Varnes (1978) and Cruden and Varnes (1996). Unit locally includes deposits of sheetwash (Qpa) and alluvium and colluvium, undivided (Qac) that are too small to map separately. Unit Qc may be susceptible to continued movement or reactivation due to natural and human-induced processes. Some of the rock fragments in unit Qc are as much as 3 m in diameter; some of the sand in the unit probably was deposited as sheetwash and debris flows. Maximum thickness possibly about 20 m. *GRI Source Map ID 75593* (SIM 3179).

Qct - Colluvium and talus (middle Pleistocene to Holocene)
Talus and colluvium variably derived from Bandelier Tuff, Cerros del Rio volcanic flows, volcaniclastic deposits, and arkosic sandstone and conglomerate of the Tesuque, Chamita, and Ancha Formations. Locally includes minor rockfall and debris flow deposits at the base of cliffs. The talus is in poorly defined, medium to thick beds. These beds slope 20-25 degrees to the east away from the basalt flows. Beds are both matrix- and clast-supported. The talus includes pebbles, cobbles, and boulders. These clasts are poorly sorted and are generally angular to subangular. Boulders may be several meters in diameter. Clasts are mostly basalt, basaltic andesite(?), and andesite, but include minor pebbles and

cobbles of quartzite (less than 2%) and granitic pebbles (generally less than 5%). The matrix is pale-brown to brown (10YR 5-6/3) silt and very fine-grained sand with slightly subordinate fine- to very coarse-grained sand. Unit includes thin (<2 m) alluvial deposits west of the Rio Grande and, in places, El Cajete tephra (~50-60 ka; Reneau et al., 1996). Surface soil possesses calcic horizon(s) with stage II or I calcium carbonate morphology. Locally, buried soils are observed. Generally loose but soils may provide some cohesion. A middle Pleistocene to Holocene age is implied by the degree of soil development. Thickness is 1-10 m, but locally along White Rock Canyon exceeds 25 m. [Description taken in part from Dethier, 1997]. *GRI Source Map ID 75477* (OFR 531).

Qco - Colluvium (Quaternary)
Poorly sorted slope wash and talus deposits from local sources; mapped only where extensive or where covering critical contacts or fault relations; mostly Holocene and Pleistocene in age; thickness can locally exceed 10 m. *GRI Source Map ID 7226* (OF-GM 111).

Qc - Colluvium (Upper Pleistocene to Holocene)
Hillslope and talus deposits from local sources. In the southern half of the quadrangle, colluvium is loose gravel primarily eroded from the gravel of Lookout Park. Most hillslopes contain a few centimeters to a meter thickness of colluvium, but unit Qc is mapped only where the thickness and distribution of colluvium prohibits confident mapping of other units. As thick as 20 m locally. *GRI Source Map ID 7218* (OF-GM 85).

Qco - Colluvium (Holocene and Pleistocene)
Poorly sorted slope wash and talus deposits from local sources; mapped only where extensive or where covering critical contact and fault relations; Holocene and Pleistocene in age; thickness can locally exceed 10 m. *GRI Source Map ID 7224* (OF-GM 42).

Qc - Colluvium (Late Pleistocene to Holocene)
Poorly-sorted talus, debris, and colluvium in wedge shaped deposits on hill slopes. Especially common where mesas and cuestas are capped by intermediate to mafic lavas or Tertiary gravels. Thickness can locally exceed 5 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qc - Colluvium (Holocene to middle Pleistocene)
Rockfall, debris-flow, and poorly sorted alluvium on steep slopes, particularly near major drainages such as Guaje and Santa Clara Canyons and along mesas capped by Bandelier Tuff. Texture and clast lithology variable. Thickness generally 3–10 m. Overlies Bandelier Tuff, Puye Formation and Santa Fe Group. Surface soils thin (<0.5 m) and weakly developed at many locations; buried soils with well-developed Bt horizons or K horizons (Birkeland, 1999) demonstrate that many deposits are polygenetic and locally older than late Pleistocene. *GRI Source Map ID 6547* (MF 2419).

Qcbt - Colluvium, wedge shaped deposits of Tshirege Member of Bandelier Tuff (Holocene to Pleistocene)

Talus debris that typically form wedge-shaped deposits adjacent to cliffs. Debris is unsorted to poorly-sorted, often obscuring faults and/or contacts between rock units. Although abundant, these deposits were mapped in only a few locations, particularly on north facing slopes. Holocene to Pleistocene in age with a maximum thickness of ~ 15 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qcta - Cerro Toledo deposits with younger alluvium and/or colluvium, undivided (Holocene to Pleistocene)

These deposits typically occur in valleys where the upper portions of the underlying Cerro Toledo tephras have been reworked and are mixed with younger alluvial and colluvial material. Younger material typically

includes reworked vitric pumices of Bandelier Tuff (Tsankawi or Tshirege Member) or clasts of devitrified Bandelier Tuff. Alluvial material may also include younger terrace deposits, with rounded cobbles and boulders of Tschicoma lavas. *GRI Source Map ID 6633* (OF-GM 55).

Qt - Terrace gravel (Holocene to Pleistocene)

Qt - Terrace gravel (Holocene to Pleistocene)
Fluvial pebble to boulder-sized gravel composed primarily of Tschicoma Formation lava or Bandelier Tuff, deposited along the edges of modern drainages at levels as much as 30 m above the present canyon floor. Terraces are particularly well developed in Rendija Canyon (Reneau and McDonald, 1996; Reneau et al., 1996). Terraces are also well preserved in eastern Pueblo Canyon, Guaje Canyon, and Sawyer Canyon. El Cajete pumice sits on a low terrace on the south side of Pueblo Canyon near the eastern edge of the map. Holocene to Pleistocene in age (Reneau, 2000) with a maximum thickness of ~ 30 meters. In Pueblo Canyon Qpct1 is the higher terrace level; Qpct2 is lower. El Cajete pumice overlies Qt2 at the eastern edge of the quadrangle. *GRI Source Map ID 6633* (OF-GM 55).

Qg - Gravelly alluvium (Holocene? and late Pleistocene)
Small, scattered deposits of gravelly stream alluvium that form small low hills along and near Arroyo Tetilla in the southern part of the map area. Unit contains deposits of pebbly and cobbly sandy gravel and pebbly and cobbly silty sand. The top of the unit is capped by a gravelly lag that is about 5 m or less above the adjacent channels of intermittent streams. Boulders as long as 1 m are locally present in the gravelly lag. Some deposits of Qg may be gravelly facies of Qac. Estimated thickness 5–10 m. *GRI Source Map ID 75593* (SIM 3179).

Qt4 - Terrace gravel (Upper Pleistocene)
Fill-terrace gravel with an upper surface approximately 18- 20 m above grade along Peralta and Cochiti Canyons. Gravel is typically no more than 3 m. On the Santo Domingo Pueblo quadrangle, Qt4 grades to a terrace along the Rio Grande that is overlain by ca. 60 ka El Cajete pumice (Smith and Kuhle, 1997a). Dethier and McCoy (1993) estimate an age of 95 ±15 ka for fill terraces at a similar elevation above grade in the Española Basin. *GRI Source Map ID 7218* (OF-GM 85).

Qt - Terrace gravel (Holocene and Pleistocene)
Slightly older alluvium that lies along the margins of present streams and basins; now undergoing erosion; mapped in only a few locations but relatively extensive along major streams such as Frijoles Creek (Reneau, 2000); Holocene and Pleistocene in age based on 14C dates (Reneau, 2000); maximum thickness as much as 15 m. *GRI Source Map ID 7224* (OF-GM 42).

Qt - Terraces (Late Pleistocene to Holocene)
Alluvial deposits near the margins of modern streams or older perched floodplain deposits. Most are fill terrace deposits of sand, silt and gravel < 10 m above modern drainages. Maximum thickness is <10 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qac - Alluvium and colluvium, undivided (Holocene and late Pleistocene?)

Chiefly undifferentiated flood plain and stream channel deposits, sheetwash (Qpa), and minor fan alluvium and debris-flow deposits, undivided (Qfd). Unit ranges from slightly pebbly, silty sand to poorly sorted, clast- and matrix-supported, locally bouldery, cobbly and pebbly gravel with a sandy matrix. Low-lying areas of the map unit are prone to periodic flooding and locally to debris-flow deposition. Deposits composed of moderately well sorted silty sand are prone to gullying. Thickness possibly about 1–10 m. *GRI Source Map ID 75593* (SIM 3179).

Qpct1 - Terrace gravel, Pueblo Canyon upper terrace level (Holocene to Pleistocene)

Fluvial pebble to boulder-sized gravel composed primarily of Tschicoma Formation lava or Bandelier Tuff, deposited along the edges of modern drainages at levels as much as 30 m above the present canyon floor. Terraces are particularly well developed in Rendija Canyon (Reneau and McDonald, 1996; Reneau et al., 1996). Terraces are also well preserved in eastern Pueblo Canyon, Guaje Canyon, and Sawyer Canyon. El Cajete pumice sits on a low terrace on the south side of Pueblo Canyon near the eastern edge of the map. Holocene to Pleistocene in age (Reneau, 2000) with a maximum thickness of ~ 30 meters. In Pueblo Canyon Qpct1 is the higher terrace level; Qpct2 is lower. El Cajete pumice overlies Qpct2 at the eastern edge of the quadrangle. *GRI Source Map ID 6633* (OF-GM 55).

Qpct2 - Terrace gravel, Pueblo Canyon lower terrace level (Holocene to Pleistocene)

Fluvial pebble to boulder-sized gravel composed primarily of Tschicoma Formation lava or Bandelier Tuff, deposited along the edges of modern drainages at levels as much as 30 m above the present canyon floor. Terraces are particularly well developed in Rendija Canyon (Reneau and McDonald, 1996; Reneau et al., 1996). Terraces are also well preserved in eastern Pueblo Canyon, Guaje Canyon, and Sawyer Canyon. El Cajete pumice sits on a low terrace on the south side of Pueblo Canyon near the eastern edge of the map. Holocene to Pleistocene in age (Reneau, 2000) with a maximum thickness of ~ 30 meters. In Pueblo Canyon Qpct1 is the higher terrace level; Qpct2 is lower. El Cajete pumice overlies Qpct2 at the eastern edge of the quadrangle. *GRI Source Map ID 6633* (OF-GM 55).

Qfd - Fan alluvium and debris-flow deposits, undivided (Holocene to Pleistocene)

Qaf - Alluvial fan deposits (Pleistocene)
Tan silt and gravel overlying Cerro Toledo deposits or Bandelier Tuff east of the Sawyer Canyon and Pajarito fault zones in the eastern part of the map area. The gravel is derived from Puye Formation eroding from the footwall of the faults. Pleistocene in age and ~1- 3 meter thick. *GRI Source Map ID 6633* (OF-GM 55).

Qfd - Fan alluvium and debris-flow deposits, undivided (Holocene to middle? Pleistocene)
Clast-and-matrix supported, locally bouldery, pebbly and cobbly gravel with a sandy matrix, and locally pebbly and cobbly, slightly silty sand that contains gravel lenses. The unit commonly forms fan-shaped and lobate masses of sediment deposited at and below the mouths of narrow valleys. Sediments were deposited by sediment-charged, intermittent streams and debris flows. Levees that contain cobbles and boulders are locally present on debris flows. Small deposits of unmapped sheetwash (Qpa) locally overlie unit Qfd. Soils formed in younger deposits have Bk horizons; those formed in older deposits have thin (about 30 cm) K horizons with strong stage III carbonate morphology. Low-lying areas of the map unit adjacent to stream channels are prone to periodic flooding and debris-flow deposition. Maximum thickness possibly about 20 m. *GRI Source Map ID 75593* (SIM 3179).

Qrx - Boulder fields (Holocene to Pleistocene)

Areas covered with boulders as large as 3m derived from subjacent rock units; generally devoid of vegetation; many appear to be rock glaciers, exhibiting flowage features such as arcuate pressure ridges (Blagbrough 1994); thickness unknown. *GRI Source Map ID 75592* (GM 79).

Qyt - Younger stream terraces (Holocene (inferred) or late Pleistocene)

Qt - Younger stream terraces (inferred Holocene or late Pleistocene)
Deposits of sand, gravel, and silt that underlie young terrace surfaces bordering present streams; maximum thickness uncertain. *GRI Source Map ID 75592* (GM 79).

Qt - Terrace gravel (Quaternary)
Slightly older alluvium that lies along the margins of present streams and basins; now undergoing erosion; mapped in only a few locations; maximum thickness as much as 15 m. *GRI Source Map ID 7226* (OF-GM 111).

Qts - Sulphur Creek terraces (Holocene to late Pleistocene)

Deposits of gravel, sand, silt, peat, and minor lacustrine beds along the edges of Sulphur Creek; maximum thickness probably 15m. *GRI Source Map ID 75592* (GM 79).

Qlso - Older landslides (late Pleistocene)

Qlso - Older landslides (Quaternary)
Older slide deposits that are overlain by El Cajete pumice; maximum exposed thickness about 25 m. *GRI Source Map ID 7225* (OF-GM 112).

Qlso - Older landslides (late Pleistocene)
Older slide deposits that are overlain by several types of younger deposits; may include Qmso in north caldera area; maximum exposed thickness about 25 m. *GRI Source Map ID 75592* (GM 79).

Qols - Older landslides (Quaternary)
Older slide deposits that are overlain by El Cajete pumice or (rarely) by the upper Bandelier Tuff; latter examples occur in San Juan Canyon in southwest part of the map; maximum exposed thickness about 25 m. *GRI Source Map ID 7226* (OF-GM 111).

Qto - Older stream terraces (late Pleistocene)

Deposits of sand, gravel, and silt that underlie higher terraces at various elevations and generally post-date lakes that occupied major valleys in the caldera; old terrace gravels along San Antonio Creek contain a variety of volcanic rocks ± rare Precambrian clasts ± Banco Bonito Flow rhyolite; terrace north of La Cueva is 29.0 ± 0.3 ka (Goff and Gardner 2004); typical thickness is 1-2 m but locally may exceed 10 m. *GRI Source Map ID 75592* (GM 79).

Qa4 - Alluvial deposit , gravel and sand (late Pleistocene)

Qa4 - Alluvial deposit 4 (late Pleistocene)
Well-sorted cobble to boulder gravel, cross-bedded sand, and thin-bedded sand of fluvial origin and fluvial and eolian silty sand beneath terrace remnants 14–20 m above the Rio Grande. Exposed mainly at mouths of tributaries such as Medio Canyon and in the southern part of the map area. Overlies Santa Fe Group deposits, landslide deposits, or older alluvium. Deposits are extensive near Cochiti Dam, where 5–10 m of axial river cobble-gravel overlies basaltic boulders and underlies piedmont alluvium mainly derived from the west. Deposits apparently lie beneath the ~55 ka El Cajete tephra. Soils <1.0 m thick and poorly exposed with Stage II or weak Stage III carbonate morphology. Thickness probably 4–20 m. *GRI Source Map ID 7228* (SIM 3194).

Qal4 - Alluvial deposits (upper Pleistocene)
Well-sorted cobble to boulder gravel, crossbedded sand, and thin-bedded sand and silty sand beneath terrace remnants 14–20 m above the Rio Grande, exposed near the mouth of Los Alamos Canyon. Clasts predominantly axial-river types; locally rich in dacitic rocks derived from the Jemez Mountains. Thickness probably 4–20 m. Overlies or inset against rocks of the Santa Fe Group. Soils less than 1.0 m thick and poorly exposed; carbonate morphology is Stage II or Stage III (Birkeland, 1999). *GRI Source Map ID 6547* (MF 2419).

Qp4 - Piedmont alluvial deposit, gravel, sand and silty sand (late Pleistocene)

Qp4 - Piedmont alluvial deposit 4 (late Pleistocene)
Poorly sorted cobble to boulder gravel, sand, and local silty sand. West of the Rio Grande, clasts are predominantly andesite and silicic tuff derived from the Jemez Mountains to the west and the matrix is rich in lithic fragments and quartz. To the east, granitic and metamorphic clasts predominate and matrix is arkosic. Deposits 0.5–8.0 m thick are exposed beneath terraces 14–20 m above present channels graded to the Rio Grande. Exposures are extensive near Rio Chiquito and south to Bland Canyon. Overlies Cochiti Formation or Otowi Member of the Bandelier Tuff. Soils generally thin (<1 m) and moderately developed having local Stage III carbonate morphology and buried Bt horizons. *GRI Source Map ID 7228* (SIM 3194).

Qtp4 - Piedmont alluvium (upper(?) Pleistocene)
Poorly sorted cobble to boulder gravel, sand, and silty sand. Clasts predominantly dacite; surface rich in boulders. Deposits mainly 0.5–1.5 m thick, locally as thick as 18.0 m, exposed beneath terraces 15–25 m above drainages graded to the Rio Grande between Chupaderos and Santa Clara Canyons. Overlies Santa Fe Group. Soils poorly exposed but generally thin (<1.0 m) and moderately developed with local Stage II carbonate (Birkeland, 1999) and buried Bt horizons. *GRI Source Map ID 6547* (MF 2419).

Qalo2 - Old alluvium (Pleistocene)

Clasts of rounded Tshcioma Formation dacite to rhyodacite and rounded Bandelier Tuff preserved in a southeast-trending paleochannel cut into Cerro Toledo deposits in upper Cabre Canyon. *GRI Source Map ID 6633* (OF-GM 55).

Qtpu - Piedmont alluvium, undivided (late to early(?) Pleistocene)

Poorly exposed cobble to boulder gravel, sand, and local eolian deposits in the western map area. Clasts predominantly dacite derived from the Tschicoma Formation. Deposits 0.5 to more than 20 m thick beneath boulder-capped terrace remnants and elongate ridges 20–40 m above local arroyos, mainly on upland surfaces. Faulted (?) terrace remnants 40–60 m above the floor of upper Chupaderos and Garcia Canyons are mapped as Qtpu, but may be older than other deposits in the western half of the map area. Overlies deposits of the Cerro Toledo interval, lower part of Bandelier Tuff, or Puye Formation. Soils poorly exposed. Several elongate ridges of unit Qtpu appear to be topographically inverted channels active during Cerro Toledo time. *GRI Source Map ID 6547* (MF 2419).

Qafo - Older alluvial fans (Pleistocene)

Older deposits within Valles caldera consist of coarse to fine gravel and sand, silt, and clay derived mostly from the volcanic domes, resurgent dome, and caldera walls; deposits commonly post date the lakes that occupied major valleys and have been incised. Alluvial fans west of Battleship Rock overlie old colluvium dominated by Paliza Canyon Formation andesite cobbles and contain rounded sandstone clasts derived from the Permian Abo Formation and Yeso Group. Various deposits are mainly

Pleistocene in age although, typically, portions are still active; thickness is unknown. *GRI Source Map ID 75592* (GM 79).

Qlec - El Cajete lake deposits (Pleistocene)

Deposits of reworked El Cajete Pyroclastic Beds and coarse sand in the Valle Grande (Qlec) that formed when pumice deposits dammed the East Fork Jemez River (Peneau et al. 2007). *GRI Source Map ID 75592* (GM 79).

Qlb - El Cajete lake deposits, constructional landforms (Pleistocene)

Deposits of reworked El Cajete Pyroclastic Beds and coarse sand in the Valle Grande (Qlec) that formed when pumice deposits dammed the East Fork Jemez River (Peneau et al. 2007); Qlb designates constructional landforms along and near the margin of the lake, including beach ridges and spits; age about 50-60 ka; maximum exposed thickness about 4 m. *GRI Source Map ID 75592* (GM 79).

Ql - Lacustrine deposits in northern caldera (Pleistocene)

Finely laminated deposits of clay, silt, and very fine sand with subordinate fine to coarse sand and gravel; deposited in lakes that occupied Valle San Antonio, Valle Toledo, and Valle Santa Rosa; formed by blockage of drainages by post-resurgence eruptions from ring-fracture vents (Rogers et al. 1996; Reneau et al. 2007); deposits sometimes tuffaceous, and diatomaceous facies present; locally may contain fossil remains; locally silicified from hydrothermal alteration; age roughly 400 to >800 ka; maximum exposed thickness about 20 m. *GRI Source Map ID 75592* (GM 79).

Qlsm - South Mountain lake deposits (Pleistocene)

Laminated to bedded, diatomaceous silty clay and mudstone; minor siltstone and sandstone; found in Valle Grande (Conover et al. 1963; Griggs 1964; Reneau et al. 2007; Fawcett et al. 2007 2011); lake formed when South Mountain Member rhyolite dammed drainage of the East Fork Jemez River; possibly interbedded with older alluvial fan deposits (Qafo); age 552 to about 368 ka; maximum drilled thickness in Valle Grande is about 95 m. *GRI Source Map ID 75592* (GM 79).

Qso - Older intracaldera sandstone (Pleistocene)

Weakly indurated to unconsolidated, moderate- to well-sorted, subrounded, medium-grained, reddish-tan quartz lithic sand with scattered pumice clasts; locally thinly crossbedded. Unit overlies northeast portions of Cerro Seco Member lava dome at 9,000 ft; maximum exposed thickness about 20 m. *GRI Source Map ID 75592* (GM 79).

Qmso - Older sedimentary deposits of northern caldera (Pleistocene)

Debris-flow, landslide, and fluvial deposits that resemble early caldera-fill sediments (Qdf, described below) but include fragments of lava and pumice from Cerro del Medio Member rhyolites; age about 1.2-0.9 Ma; maximum exposed thickness about 25 m. *GRI Source Map ID 75592* (GM 79).

Qdf - Early caldera-fill debris-flow, landslide, alluvium, and colluvium deposits (Pleistocene)

Matrix-supported conglomerates containing particles ranging in size from clay to boulders of various early postcaldera rhyolites, Bandelier Tuff, precaldera volcanic rocks, Miocene to Permian sandstone, Pennsylvanian limestone, and Precambrian crystalline rocks; finer-grained matrix is generally not exposed; contains minor fluvial sand and gravel deposits; lower part of unit displays extensive, low-grade hydrothermal alteration (Chipera et al. 2007); interbedded with and overlies all other units on resurgent dome; age is 1.25 to 1.0 (?) Ma; maximum exposed thickness is 70 m; maximum drilled thickness in Baca-7 well on northeast side of resurgent dome is more than 400 m (Lambert and Epstein 1980). *GRI Source Map ID 75592* (GM 79).

Qvsc - Early caldera-fill lacustrine and fluvial deposits, abundant biotite from weathered Redondo Creek rhyodacite (Pleistocene)

Consists of sandstone, siltstone, and lacustrine beds containing abundant biotite from weathering of Redondo Creek Member rhyodacite; beds generally display zeolitic or less commonly acid sulfate alteration (Chipera et al. 2007); beds generally deformed by uplift of resurgent dome; age is 1.25-1.1 (2) Ma; maximum exposed thickness about 30 m. *GRI Source Map ID 75592* (GM 79).

Qst - Sinter deposits (Pleistocene)

Small, widely scattered outcrops of massive to banded silica-rich hot spring deposits from early hydrothermal activity on resurgent dome; may contain Fe-oxides; may contain fossil reeds and other organic remains; maximum exposed thickness about 3 m. *GRI Source Map ID 75592* (GM 79).

Qvs - Early caldera-fill lacustrine and fluvial deposits (Pleistocene)

Laminated to thinly bedded, diatomaceous mudstone and siltstone, and crossbedded to normally graded sandstone and conglomerate; some beds contain ripple marks, flute casts, and plane laminations and may be deltaic deposits near margins of initial caldera lake. *GRI Source Map ID 75592* (GM 79).

Qvb - Valles Rhyolite, Banco Bonito Flow (Pleistocene)

Thick rhyolite lava flows that contain phenocrysts of plagioclase, quartz, biotite, hornblende, clinopyroxene, and rare sanidine in a glassy to devitrified groundmass; upper surface of unit preserves pressure ridges and valleys with as much as 20 m of relief; fills paleovalleys in southern ring-fracture zone; unit dated at 34-45 ka (Ogoh et al. 1993; Phillips et al. 1997; Goff and Gardner 2004; Lepper and Goff 2007); magnetic polarity normal; maximum exposed thickness roughly 140 m. *GRI Source Map ID 75592* (GM 79).

Qg3 - Sedimentary deposits of southern caldera, episode 3 (Pleistocene)

Alluvium, colluvium, debris flows, and minor lacustrine deposits interbedded with silicic lavas and pyroclastic rocks in the southern Valles caldera; formed during at least three episodes of incision and blockage of the ancestral East Fork Jemez River and tributaries. Qg3 underlies the Banco Bonito Flow rhyolite (Qvb) but overlies El Cajete Pyroclastic Beds (Qvec) and Battleship Rock Ignimbrite (Qvbr); maximum exposed thickness is about 40 m. *GRI Source Map ID 75592* (GM 79).

Qvec - Valles Rhyolite, El Cajete Pyroclastic Beds (Pleistocene)

Qvec - El Cajete pyroclastic beds (Pleistocene)
White to tan, moderately sorted, pyroclastic fall deposits of vesicular rhyolite; pumice clasts contain sparse phenocrysts of plagioclase, quartz, and biotite with rare microphenocrysts of hornblende and clinopyroxene; some clasts contain resorbed quartz with pale green, clinopyroxene reaction rims; originated from El Cajete crater (Bailey et al., 1969; Smith et al., 1970; Gardner et al., 1986; Self et al., 1988; Wolff et al.,1996; Gardner et al., 2010); maximum diameter of clasts is about 50 cm near vent but clast size diminishes away from source; contains relatively abundant lithic clasts of Bandelier Tuff and precaldera volcanic rocks but rare Paleozoic and Precambrian rocks; overlies South Mountain rhyolite and various sedimentary deposits; unit dated at about 50 to 60 ka (Toyoda et al., 1995; Reneau et al., 1996); unit extensively reworked by erosion, collecting on south and east facing slopes; maximum exposed thickness about 20 m in valleys of the southeastern map area; thins on mesa tops and hills forming scant exposures too thin or small to map. *GRI Source Map ID 7225* (OF-GM 112).

Qec - El Cajete tephra (late Pleistocene)
White to gray, poorly sorted rhyolitic pumice fall deposits; pumice clasts contain sparse phenocrysts of quartz, sanidine, biotite, and clinopyroxene. Most exposures have been reworked and concentrated by fluvial or slope processes. Overlies buried soil containing a well-developed Bt horizon invaded by carbonate. Derived from the El Cajete vent in the Valles Caldera (fig. 1); age ~50 to 60 ka (Reneau and others, 1996). Exposed in local, dune-like outcrops as thick as 8 m. *GRI Source Map ID 7228* (SIM 3194).

Qvec - El Cajete Pyroclastic Beds (Pleistocene)
Moderately sorted beds of pyroclastic fall and thin pyroclastic flow deposits; rhyolite pumice clasts contain sparse phenocrysts of plagioclase, quartz, and biotite with rare microphenocrysts of hornblende and clinopyroxene; unit dated at about 50-60 ka (Toyoda et al. 1995; Reneau et al. 1996); magnetic polarity normal (Geissman 1988); maximum exposed thickness varies from 70 m in vent area to scant exposures too thin to map. *GRI Source Map ID 75592* (GM 79).

Qvec - El Cajete Pyroclastic Beds, East Fork Member (Pleistocene)
White to beige pyroclastic fall deposits containing pumice, ash, crystals, and lithic fragments. The pumice contains < 10% phenocrysts of quartz sanidine, and biotite. The deposits in this area are not primary, but are reworked. 50 to 60 ka (Reneau et al., 1996). < 1 m thick. *GRI Source Map ID 6633* (OF-GM 55).

Qec - El Cajete Member of the Valles Rhyolite (late Pleistocene)
Small scattered deposits of white, coarse sand- to small pebble-size (0.5–12 mm) pumice fragments that locally mantle hill slopes in the northern part of the map area. The pumice is about 50–60 ka and was erupted from the nearby Valles caldera (Bailey and others, 1969; Reneau and others, 1996a), about 20 km northwest of the map area (fig. 1). Some or much of Qec was redeposited by alluvial and possibly by mass-movement or eolian processes. Maximum thickness possibly about 5 m. *GRI Source Map ID 75593* (SIM 3179).

Qect - El Cajete tephra (lower Pleistocene)
Pyroclastic-fall deposits of white, vesicular, pumice lapilli of rhyolitic composition that were erupted from the El Cajete crater within the southwestern Valles caldera. Vesicular pumice lapilli contain phenocrysts of quartz (some with clinopyroxene reaction rims), biotite, and plagioclase with rare microphenocrysts of hornblende and clinopyroxene. Most exposures have been reworked by slope processes. Miyaji et al. (1985) report a zircon-fission-track age of 170 ± 70 ka. Toyoda et al. (1995) and Toyodo and Goff (1996) interpret ESR ages of about 53 ± 6 ka for El Cajete and 59 ± 6 ka Battleship Rock Members. Reneau et al. (1996) obtained thermal luminescence ages of 48 ± 5 to 61 ± 5ka for soils buried beneath the El Cajete fallout pumice, and a 14C age >50 ka for charcoal within the pumice deposit. Generally less than

1 m-thick. [Description is from Dethier, 1997; Sawyer et al., in review]. *GRI Source Map ID 75477* (OFR 531).

Qec - El Cajete pumice (Quaternary)
White to tan, moderately sorted, pyroclastic fall deposits of vesicular rhyolite; pumice clasts contain sparse phenocrysts of plagioclase, quartz, and biotite with rare microphenocrysts of hornblende and clinopyroxene; some clasts contain resorbed quartz with pale green, clinopyroxene reaction rims; originated from El Cajete crater and is part of the El Cajete Series (Bailey et al., 1969; Smith et al., 1970; Gardner et al., 1986; Self et al., 1988; Wolff et al., 1996); maximum diameter of clasts is about 50 cm near vent but clast size diminishes away from source; contains relatively abundant lithic clasts of Bandelier Tuff and precaldera volcanic rocks but rare Paleozoic and Precambrian rocks; also contains blocks of black glassy rhyolite near vent; includes pyroclastic surge deposits in near-vent areas; underlies Banco Bonito rhyolite and various sedimentary deposits; upper part of unit includes thin ignimbrites of Battleship Rock tuff; overlies South Mountain Rhyolite and various sedimentary deposits; unit dated at about 50 to 60 ka (Toyoda et al., 1995; Reneau et al., 1996); unit extensively reworked by erosion, collecting on south and east facing slopes; maximum exposed thickness about 70 m in vent area and as much as 50 m in valleys of the southern map area; thins on mesa tops and hills forming scant exposures too thin or small to map. *GRI Source Map ID 7226* (OF-GM 111).

Qec - El Cajete Member Pumice, Valles Rhyolite (Upper Pleistocene)
Discontinuous sheetwash and fluvially reworked rhyolite pumice-fall deposit, typically less than 5 m thick. Also includes poorly to moderately sorted primary deposits that occur along the Pajarito fault zone and in Bland Canyon. Pumice clasts are white to tan, vesicular, and typically less than 7 cm in diameter. They contain less than 2% phenocrysts of quartz, sanidine, biotite, and rare clinopyroxene and hornblende. Erupted approximately 60 ka from the El Cajete crater in southern moat of Valles caldera. Quarried in many locations. Maximum thickness about 10 m. *GRI Source Map ID 7218* (OF-GM 85).

Qvec - El Cajete pumice, El Cajete Member of Valles Rhyolite (Quaternary)
White to tan, moderately sorted, pyroclastic fall deposits of vesicular rhyolite; pumice clasts contain sparse phenocrysts of quartz, biotite, and plagioclase with rare microphenocrysts of hornblende and clinopyroxene; some clasts contain resorbed quartz with pale green, clinopyroxene reaction rims; maximum diameter of clasts about 15 cm but clast size diminishes from west to east away from source; unit forms extensive mesa top cover in Bandelier National Monument (BNM) and southern LANL; unit extensively reworked by erosion and collects on east facing slopes and on benches cut into upper flow unit and/or cooling unit boundaries of Tshirege Member, Bandelier Tuff; Qvec originated west of map area from El Cajete crater in southern moat of Valles caldera (Bailey et al., 1969; Smith et al., 1970; Gardner et al., 1986; Self et al., 1988; Wolff et al., 1996); unit dated at about 50 to 60 ka (Toyoda et al., 1995; Reneau et al., 1996); maximum exposed thickness about 10 m in southwest map area; thins to northeast on mesa tops. *GRI Source Map ID 7224* (OF-GM 42).

Qec - El Cajete Member tephra, Valles Ryolite (Quaternary)
White to beige pyroclastic fall deposits, including pumice, ash, crystals, and lithic fragments associated with the ~50 to 60 ka eruption of the El Cajete Member of the Valles Rhyolite (Reneau et al., 1996). Primary deposits are exposed in at least 2 active mines in the northwest corner of the quadrangle where the unit is poorly to moderately sorted. Typically, however, exposures of this unit are reworked, displaying few bedding features. Phenocryst content of pumices is generally less than 10% and includes quartz, sanidine, and biotite. Many of the hills in the northern portion of the quadrangle are covered with >1 meter of primary or reworked tephra. To the south the tephra thins significantly and typically is exposed as isolated patches along hillslopes or capping terrace and other alluvial deposits along drainage bottoms. Maximum thickness in primary deposits exceeds 5 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qvbr - Valles Rhyolite, Battleship Rock Ignimbrite (Pleistocene)

Rhyolitic pyroclastic flows and surge deposits with lithic clasts; pumice contains phenocrysts of plagioclase, quartz, biotite, hornblende, clinopyroxene, and rare sanidine; smaller ignimbrites interbedded with the upper part of the El Cajete Pyroclastic Beds pumice; mostly fills paleocanyons in southwestern moat of Valles caldera; estimated age is 50-60 ka (Toyoda et al. 1995; Reneau et al. 1996); magnetic polarity normal; maximum exposed thickness about 60 m. *GRI Source Map ID 75592* (GM 79).

Qg2 - Sedimentary deposits of southern caldera, episode 2 (Pleistocene)

Alluvium, colluvium, debris flows, and minor lacustrine deposits interbedded with silicic lavas and pyroclastic rocks in the southern Valles caldera; formed during at least three episodes of incision and blockage of the ancestral East Fork Jemez River and tributaries. Qg2 overlies South Mountain Member rhyolite (Qvsm4 to Qvsm1) but underlies the El Cajete Pyroclastic Beds (Qvec) and Battleship Rock Ignimbrite (Qvbr); maximum exposed thickness is about 40 m. *GRI Source Map ID 75592* (GM 79).

Qvsm4 - Valles Rhyolite, South Mountain Member, fourth flow (Pleistocene)

\Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing abundant phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene in a pale-gray, perlitic to white, devitrified groundmass; apparently consists of four flow units based on morphology (youngest to oldest Qvsm4 to Qvsm1); fills paleocanyon in southern moat of Valles caldera; maximum exposed thickness is at least 450 m. *GRI Source Map ID 75592* (GM 79).

Qvsm3 - Valles Rhyolite, South Mountain Member, third flow (Pleistocene)

Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing abundant phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene in a pale-gray, perlitic to white, devitrified groundmass; apparently consists of four flow units based on morphology (youngest to oldest Qvsm4 to Qvsm1); fills paleocanyon in southern moat of Valles caldera; maximum exposed thickness is at least 450 m. *GRI Source Map ID 75592* (GM 79).

Qvsm2 - Valles Rhyolite, South Mountain Member, second flow (Pleistocene)

Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing abundant phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene in a pale-gray, perlitic to white, devitrified groundmass; apparently consists of four flow units based on morphology (youngest to oldest Qvsm4 to Qvsm1); fills paleocanyon in southern moat of Valles caldera; 40Ar/39Ar age of Qvsm2 is 0.52 0.01 Ma (Spell and Harrison 1993); maximum exposed thickness is at least 450 m. *GRI Source Map ID 75592* (GM 79).

Qvsm1 - Valles Rhyolite, South Mountain Member, first flow (Pleistocene)

Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing abundant phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene in a pale-gray, perlitic to white, devitrified groundmass; apparently consists of four flow units based on morphology (youngest to oldest Qvsm4 to Qvsm1); fills paleocanyon in southern moat of Valles caldera; maximum exposed thickness is at least 450 m. *GRI Source Map ID 75592* (GM 79).

Qvlj - Valles Rhyolite, Cerro La Jara rhyolite (Pleistocene)

Small dome of flow-banded, massive to slightly vesicular porphyritic lava; 40Ar/39Ar age is 0.53 ± 0.01 Ma (Spell and Harrison 1993); magnetic polarity normal; maximum exposed thickness about 75 m. *GRI Source Map ID 75592* (GM 79).

Qg1 - Sedimentary deposits of southern caldera, episode 1 (Pleistocene)

Alluvium, colluvium, debris flows, and minor lacustrine deposits interbedded with silicic lavas and pyroclastic rocks in the southern Valles caldera; formed during at least three episodes of incision and blockage of the ancestral East Fork Jemez River and tributaries. Qg1 underlies the South Mountain Member rhyolite (Qvsm4 to Qvsm1); maximum exposed thickness is about 40 m. *GRI Source Map ID 75592* (GM 79).

Qvsa3 - Valles Rhyolite, San Antonio Mountain Member, flow 3 and peripheral vent (Pleistocene)

Flow -banded, massive to slightly vesicular rhyolite lavas containing phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene; third flow and peripheral vent (Qvsa3) may be present at Sulphur Point; magnetic polarity normal; maximum exposed thickness at least 510 m. *GRI Source Map ID 75592* (GM 79).

Qvsa2 - Valles Rhyolite, San Antonio Mountain Member, flow 2 (Pleistocene)

Flow -banded, massive to slightly vesicular rhyolite lavas containing phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene; consists of two main flow units based on morphology (Qvsa2 and Qvsa1) erupted from San Antonio Mountain; magnetic polarity normal; maximum exposed thickness at least 510 m. *GRI Source Map ID 75592* (GM 79).

Qvsa1 - Valles Rhyolite, San Antonio Mountain Member, flow 1 (Pleistocene)

Flow -banded, massive to slightly vesicular rhyolite lavas containing phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene; consists of two main flow units based on morphology (Qvsa2 and Qvsa1) erupted from San Antonio Mountain; 40Ar/39Ar age of Qvsa1 is 0.557± 0.004 Ma (Spell and Harrison 1993); magnetic polarity normal; maximum exposed thickness at least 510 m. *GRI Source Map ID 75592* (GM 79).

Qvse2 - Valles Rhyolite, Cerro Seco Member, flow 2 (Pleistocene)

Flow -banded, massive to slightly vesicular rhyolite lavas containing phenocrysts of quartz, sanidine, biotite, and rare hornblende; consists of two flow units based on morphology (Qvse2 and Qvse1); 40Ar/39Ar age is 0.800 ± 0.007 Ma (Spell and Harrison 1993); magnetic polarity reverse; maximum exposed thickness is 375 m. *GRI Source Map ID 75592* (GM 79).

Qvse1 - Valles Rhyolite, Cerro Seco Member, flow 1 (Pleistocene)

Flow -banded, massive to slightly vesicular rhyolite lavas containing phenocrysts of quartz, sanidine, biotite, and rare hornblende; consists of two flow units based on morphology (Qvse2 and Qvse1); 40Ar/39Ar age is 0.800 ± 0.007 Ma (Spell and Harrison 1993); magnetic polarity reverse; maximum exposed thickness is 375 m. *GRI Source Map ID 75592* (GM 79).

Qvset - Valles Rhyolite, Cerro Seco Member, pyroclastic deposits (Pleistocene)

Pyroclastic deposits consisting of ignimbrite and dry surge near the vent, to probable hydromagmatic surge and derivative pumice-rich sediments distally; pumice lapilli have same mineralogy as flows; dates on pumice in ignimbrite and hydromagmatic deposit are 0.77 0.03 and 0.78 ± 0.04 Ma, respectively (Kelley et al., in press); thickness of all pyroclastic deposits ranges from roughly 75 m at north edge of dome complex to <1 m at distal sites. *GRI Source Map ID 75592* (GM 79).

Qtoal - Valles Rhyolite, Older alluvium (Pleistocene)

Qalo - Older alluvium (Quaternary)
Older deposits of gravel, sand and silt that largely pre-date incision of canyons on the Pajarito Plateau; gravels consist of volcanic fragments, particularly porphyritic dacite, andesite, and welded ignimbrite from sources in Sierra de los Valles to the west; deposit along Highway 4 near SE margin of Valles caldera contains rare rhyolite, Tertiary sandstone and Precambrian fragments; underlies El Cajete pumice, younger alluvial fans and younger landslides; roughly contemporaneous with older alluvial fan deposits and landslides; overlies Tshirege Member, Bandelier Tuff and dacite of Cerro Grande; maximum exposed thickness about 6 m. *GRI Source Map ID 7225* (OF-GM 112).

Qalo - Older alluvium (Pleistocene)
Gravel, sand, and silt generally overlying the Tshirege Member of the Bandelier Tuff on the rim and flanks of Valles caldera; largely pre-date incision of canyons in surrounding plateaus and highlands; gravels consist primarily of volcanic fragments from sources near the deposits and possibly from within the caldera; roughly contemporaneous in age to north caldera sediments (Qmso) and early caldera debris flows (Qdf); maximum exposed thickness about 6 m. *GRI Source Map ID 75592* (GM 79).

SRC_SYM - Older alluvium (Pleistocene)
In the town site of Los Alamos, this unit is largely composed of alternating gravel and sandstone layers of fluvial origin interbedded with beds of tephra. Some gravel lenses are dominated by pumice, but most lenses contain subequal amounts of pumice and Tchicoma Formation lava, and rare flow-banded rhyolite and obsidian granule- to pebble-sized gravel. The tephra beds are <1 m thick; the pumice is likely derived from the Cerro del Medio dome to the west of Los Alamos erupted at ~ 1.1 Ma (Spell and Harrison, 1993). The older alluvium is well exposed in a road cut just southwest of the Larry R. Walkup Aquatic Center on Canyon Road in Los Alamos. Northeast of Los Alamos, the unit is dominantly gravel, including clasts of Bandelier Tuff; pumice is absent in these deposits. The older alluvium generally sits on Bandelier Tuff. North of Los Alamos, Qalo contains abundant clasts of streaky, flow-banded rhyolite lava, black, grassy tuff, and some obsdian. Qalo was deposited as fans shortly after the eruption of the Bandelier Tuff prior to the development of the modern drainage system (Reneau. Pleistocene in age with a maximum thickness of ~ 30 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qoa - Older alluvium (Lower Pleistocene?)
Alluvial gravel and sand locally underlying Bandelier Tuff north of Peralta Canyon. Delineates paleodrainages incised into the Peralta Tuff Member of the Bearhead Rhyolite, Cochiti Formation, and gravel of Lookout Park, and later filled by the BandelierTuff. Thickness is typically 1-3 m. *GRI Source Map ID 7218* (OF-GM 85).

Qoal - Older alluvium (Quaternary)
Older deposits of gravel, sand and silt that largely predate incision of canyons on the Pajarito Plateau; gravels consist of volcanic fragments, particularly porphyritic dacite, andesite, and welded ignimbrite, from sources to west; underlies El Cajete pumice, younger alluvial fans and younger landslides; roughly

contemporaneous with older alluvial fan deposits and landslides; overlies Tshirege Member, Bandelier Tuff; may contain interbedded lapilli and ash deposits =1 m thick from Cerro del Medio rhyolite dome complex in Valles caldera (Reneau et al., 1995; Reneau and McDonald, 1996; Gardner et al., 2001), indicating a maximum age of at least 1.1 Ma (Spell and Harrison, 1993; Izett and Obradovich, 1994); maximum exposed thickness about 6 m. *GRI Source Map ID 7224* (OF-GM 42).

Qoal - Older alluvium (Late Pleistocene)
Composed of alternating gravel and sandstone layers of fluvial origin. Qoal was deposited as fans shortly after the eruption of the Bandelier Tuff prior to the development of the modern drainage system. Maximum thickness of ~ 24 meters. *GRI Source Map ID 6630* (OF-GM 74).

QToa - Older alluvial deposits (lower Pleistocene and upper Pliocene(?))
Well-sorted pebble gravel and beds of coarse sand and overlying eolian and fine-grained fluvial deposits on mesa tops exposed from Canada de las Marias to the southeast map area. Clasts rich in axial-river types (see General notes); matrix arkosic. Exposed locally about 180–240 m above the Rio Grande at elevations of about 6,100–6,300 ft. Thickness mainly 1–5 m; overlies upper Pliocene(?) lacustrine facies of the Puye Formation. Includes an isolated outcrop north of Otowi Bridge (Rio Grande at south border of map), 145 m above the Rio Grande, that overlies Pliocene basalt and contains clasts of Bandelier Tuff pumice, axial gravel, and dacitic boulders. Soils poorly exposed. *GRI Source Map ID 6547* (MF 2419).

Qvsl2 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 2 (Pleistocene)

Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing phenocrysts of sanidine, quartz, and biotite; locally spherulitic; dome consists of two eruptive pulses based on morphology (Qvsl2 and Qvsl1). 40Ar/39Ar age is 0.800 0.003 Ma (Spell and Harrison 1993); magnetic polarity reverse; maximum exposed thickness is 325 m. *GRI Source Map ID 75592* (GM 79).

Qvsl1 - Valles Rhyolite, Cerro San Luis Member, eruptive pulse 1 (Pleistocene)

Flow-banded, massive to slightly vesicular porphyritic rhyolite lavas containing phenocrysts of sanidine, quartz, and biotite; locally spherulitic; dome consists of two eruptive pulses based on morphology (Qvsl2 and Qvsl1). 40Ar/39Ar age is 0.800 0.003 Ma (Spell and Harrison 1993); magnetic polarity reverse; maximum exposed thickness is 325 m. *GRI Source Map ID 75592* (GM 79).

Qvsr2 - Valles Rhyolite, Cerro Santa Rosa Member, north dome (Pleistocene)

Two temporally distinct, juxtaposed rhyolite domes that have the same name. North dome (Qvsr2) consists of massive to flow-banded porphyritic lava with quartz, subordinate sanidine, and trace biotite; dated by 40Ar/39Ar at 0.787 ± 0.015 Ma (Spell and Harrison 1993); magnetic polarity reverse; maximum thickness about 150 m. *GRI Source Map ID 75592* (GM 79).

Qvsr1 - Valles Rhyolite, Cerro Santa Rosa Member, south dome (Pleistocene)

Two temporally distinct, juxtaposed rhyolite domes that have the same name. South dome (Qvsr1) consists of porphyritic lava with abundant quartz, subordinate sanidine, and sparse, small biotite; dome exhibits a breccia apron around summit; dated by 40Ar/39Ar at 0.914 0.004 Ma (Spell and Harrison 1993) and 0.936 ± 0.008 Ma (Singer and Brown 2002); magnetic polarity transitional; maximum thickness more than 240 m. *GRI Source Map ID 75592* (GM 79).

Qvsrt - Valles Rhyolite, Cerro Santa Rosa Member, pyroclastic flow (Pleistocene)

Pyroclastic flow and fall deposits consisting of pumice lapilli with phenocrysts of quartz, sanidine, and biotite in a highly vesicular groundmass; fall deposits contain abundant lithic fragments; 40Ar/39Ar age on pumice in pyroclastic flow is 0.91 0.03 Ma (Kelley et al., in press) and is therefore related to Qvsr1 eruption; maximum thickness is about 25 m. *GRI Source Map ID 75592* (GM 79).

Qvda4 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, small sanidine phenocrysts (Pleistocene)

Complex of four rhyolite dome and flow sequences: devitrified lava (Qvda4) with small phenocrysts of sanidine, subordinate quartz and plagioclase, and trace biotite and hornblende; maximum exposed thickness about 255 m; Composite 40Ar/39Ar age for the entire complex is 0.973 0.010 Ma (Spell and Harrison 1993); magnetic polarity normal. *GRI Source Map ID 75592* (GM 79).

Qvda3 - Valles Rhyolite, Cerros del Abrigo Member, devitrified lava, large sanidine phenocrysts (Pleistocene)

Complex of four rhyolite dome and flow sequences: devitrified lava (Qvda3) with large phenocrysts of sanidine, lesser amounts of plagioclase, large but sparse quartz, sparse biotite, and rare hornblende; maximum exposed thickness about 245 m; Composite 40Ar/39Ar age for the entire complex is 0.973 0.010 Ma (Spell and Harrison 1993); magnetic polarity normal. *GRI Source Map ID 75592* (GM 79).

Qvda2 - Valles Rhyolite, Cerros del Abrigo Member, perlitic lava (Pleistocene)

Complex of four rhyolite dome and flow sequences: perlitic lava (Qvda2) with phenocrysts of sanidine, subordinate plagioclase, sparse biotite and quartz, and trace hornblende; maximum exposed thickness about 405 m; Composite 40Ar/39Ar age for the entire complex is 0.973 0.010 Ma (Spell and Harrison 1993); magnetic polarity normal. *GRI Source Map ID 75592* (GM 79).

Qvda1 - Valles Rhyolite, Cerros del Abrigo Member, perlitic porphyritic lava (Pleistocene)

Complex of four rhyolite dome and flow sequences: apron of perlitic, porphyritic lava (Qvda1) exposed on erosional platforms around south side of dome complex; phenocrysts consist of sanidine, subordinate plagioclase and quartz, sparse biotite, and trace hornblende; maximum exposed thickness about 65 m. Composite 40Ar/39Ar age for the entire complex is 0.973 0.010 Ma (Spell and Harrison 1993); magnetic polarity normal. *GRI Source Map ID 75592* (GM 79).

Qvdmt - Valles Rhyolite, Cerro del Medio Member, pyroclastic flow and pumice fall deposits (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): pyroclastic flow and pumice-fall deposits (Qvdmt); pumice is sparsely porphyritic with small sanidine and opaque oxides; unit is likely associated with summit eruption of Qvdm6 based on mineral similarities; maximum thickness about 4 m. *GRI Source Map ID 75592* (GM 79).

Qvdm6 - Valles Rhyolite, Cerro del Medio Member, massive devitrified vesicular lava (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): massive, devitrified, vesicular lava (Qvdm6) with sparse, small phenocrysts of sanidine and opaque oxides; maximum exposed thickness about 45 m. The three oldest flow lobes do not permit discrimination of their sequence; thus, they are designated north, west, and south, respectively. *GRI Source Map ID 75592* (GM 79).

Qvdm5 - Valles Rhyolite, Cerro del Medio Member, upheaved dome of glassy to devitrified lava (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): upheaved dome of glassy to devitrified lava (Qvdm5) with very sparse sanidine phenocrysts and extremely rare clinopyroxene and zircon; maximum exposed thickness about 215 m. The three oldest flow lobes do not permit discrimination of their sequence; thus, they are designated north, west, and south, respectively. *GRI Source Map ID 75592* (GM 79).

Qvdm4 - Valles Rhyolite, Cerro del Medio Member, massive aphyric obsidian flow (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): massive, aphyric obsidian flow (Qvdm4) that is flow banded and devitrified around unit margins; 40Ar/39Ar age is 1.169 ± 0.005 Ma (E. Phillips, unpubl. data); exposed thickness about 260 m. The three oldest flow lobes do not permit discrimination of their sequence; thus, they are designated north, west, and south, respectively. *GRI Source Map ID 75592* (GM 79).

Qvdmn - Valles Rhyolite, Cerro del Medio Member, vesicular flow-baned glassy to devitrified lava (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): Vesicular, flow-banded, glassy to devitrified lava (Qvdmn) with sparse phenocrysts of sanidine and rare clinopyroxene; maximum exposed thickness about 30 m. *GRI Source Map ID 75592* (GM 79).

Qvdmw - Valles Rhyolite, Cerro del Medio Member, obsidian flow (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): Obsidian flow (Qvdmw) is locally devitrified and flow banded; nearly aphyric with small sanidine and very sparse magnetite; maximum exposed thickness about 120 m. *GRI Source Map ID 75592* (GM 79).

Qvdms - Valles Rhyolite, Cerro del Medio Member, flow-banded sparsely porphyritic lava (Pleistocene)

Rhyolite dome and flow complex consisting of at least six eruptive phases (Gardner et al. 2007): flow-banded, sparsely porphyritic lava (Qvdms) with phenocrysts of sanidine, hornblende, quartz, and rare plagioclase; 40Ar/39Ar age is 1.229 ± 0.017 Ma (Phillips et al. 2007); obsidian flows are source of many artifacts (Baugh and Nelson 1987; Steffen 2005); maximum exposed thickness about 75 m; magnetic polarity reverse. *GRI Source Map ID 75592* (GM 79).

Qrc - Valles Rhyolite, Redondo Creek Member (Pleistocene)

Massive to flow-banded, porphyritic rhyodacite lavas containing plagioclase, biotite, clinopyroxene, and sanidine phenocrysts in a perlitic to devitrified groundmass; commonly spherulitic; contains substantial flow breccia; only silicic lavas in Valles caldera that do not contain quartz; unit displays extensive hydrothermal alteration; 40Ar/39Ar ages of four domes and flows range from 1.24 to 1.21 Ma (Phillips et al. 2007); sediments are interbedded with the rhyodacite north of La Cueva; maximum exposed thickness is about 180 m. *GRI Source Map ID 75592* (GM 79).

Qrd2 - Valles Rhyolite, Young Rabbit Mountain debris-flow deposits (Pleistocene)

Two debris-flow deposits overlying the Tshirege Member of the Bandelier Tuff immediately south of Rabbit Mountain; general features resemble those of Qrd1 except the matrix is not as ash rich; maximum exposed thickness is about 60 m. *GRI Source Map ID 75592* (GM 79).

Qdc - Valles Rhyolite, Deer Canyon Member (Pleistocene)

Rhyolitic lava flows and tuffs characterized by phenocrysts of sanidine and quartz; porphyritic lavas are present on southwestern resurgent dome, whereas aphyric lavas are on central and eastern resurgent dome; 40Ar/39Ar ages of three flows range from 1.28 to 1.25 Ma (Phillips et al. 2007); maximum exposed thickness about 40 m. *GRI Source Map ID 75592* (GM 79).

Qdct - Valles Rhyolite, Deer Canyon Member, lithic and crystal rich thin-bedded rhyolitic tuffs (Pleistocene)

Lithic- and crystal-rich, thin-bedded rhyolitic tuffs (Qdct) are interbedded with lavas; pumice fragments usually contain phenocrysts of quartz and sanidine; lithic fragments generally consist of Bandelier Tuff and precaldera volcanic rocks; finer beds locally contain accretionary lapilli and appear to be hydromagmatic surge in origin; 40Ar/39Ar ages of five tuffs range from 1.27 to 1.23 Ma (Phillips et al. 2007); all units are extensively altered to zeolites, silica, Fe-oxides, and clay (Chipera et al. 2007); maximum exposed thickness about 30 m. *GRI Source Map ID 75592* (GM 79).

Qcvm - Cerro Toledo Formation, Virgin Mesa Member (Pleistocene)

Gravel and sand deposits interbedded between the two upper members of the Bandelier Tuff within or around the south and west margins and outer flanks of Valles caldera; consists primarily of precaldera volcanic rocks, Otowi Member of the Bandelier Tuff ± Valle Toledo Member rhyolite and Permian sandstone; equivalent to the intracaldera S3 sandstone of Nielson and Hulen (1984); equivalent in time to the Cerro Toledo interval (Broxton and Reneau 1995) but has no Valle Toledo Member pumice; maximum exposed thickness is 15 m. *GRI Source Map ID 75592* (GM 79).

Qcpc - Cerro Toledo Formation, Pueblo Canyon Member (Pleistocene)

Colluvial deposit of reworked pumice and angular blocks of Otowi Member tuff in middle Frijoles Canyon; two thin deposits of primarily Tschicoma Formation-derived gravels in upper Frijoles Canyon and northwest of Rendija Peak; interbedded between the two upper members of the Bandelier Tuff; equivalent to the Cerro Toledo interval (Broxton and Reneau 1995); maximum thickness about 4 m. *GRI Source Map ID 75592* (GM 79).

Qcr - Cerro Toledo Formation, aphyric rhyolite (Pleistocene)

Two dome and flow complexes and two small intrusive bodies of flow-banded lava; obsidian phases are completely aphyric and probable source of artifacts (Steffen 2005); devitrified phases contain spherulites and very sparse microphenocrysts of quartz, sanidine, and biotite; K-Ar age of dome northwest of Cerro Rubio (Ttcr) is 1.33 ± 0.02 Ma (Sfix et al. 1988); maximum exposed thickness is 365 m. *GRI Source Map ID 75592* (GM 79).

Qcrt - Cerro Toledo Formation, Valle Toledo Member, Rhyolite tuff (Pleistocene)

Two areas of partially to densely welded, nearly aphyric tuff; microphenocrysts consist of sparse quartz, sanidine, biotite, and rare clinopyroxene; K-Ar age of west exposure (Pinnacle Peak) is 1.20 ± 0.02 Ma (Stix et al. 1988); maximum exposed thickness is roughly 200 m. *GRI Source Map ID 75592* (GM 79).

Qcws - Cerro Toledo Formation, Valle Toledo Member, Warm Springs rhyolite (Pleistocene)

Small dome of massive to flow-banded, porphyritic lava containing phenocrysts of quartz, sanidine, and biotite; 40Ar/39Ar age is 1.26 ± 0.01 Ma (Spell et al. 1996); maximum exposed thickness is 25 m. *GRI Source Map ID 75592* (GM 79).

Qctq - Cerro Toledo Formation, Valle Toledo Member, Cerro Trasquilar rhyolite (Pleistocene)

Flow-banded to massive, sparsely porphyritic lava with tiny phenocrysts of quartz, sanidine, clinopyroxene, opaque oxides, and rare biotite; erupted from a single vent; 40Ar/39Ar age is 1.36 ± 0.01 Ma (Spell et al. 1996); maximum exposed thickness 225 m. *GRI Source Map ID 75592* (GM 79).

Qrd1 - Cerro Toledo Formation, Valle Toledo Member, Old Rabbit Mountain debris-flow deposits (Pleistocene)

Debris flows formed by multiple failures of the Rabbit Mountain dome during growth; outcrops display sintered ashy matrix suggesting formation as glowing avalanches; contains abundant obsidian blocks that are a known source of artifacts (Steffen 2005); forms southeast-trending hummocky tongue 5 km long and 3 km wide between the two upper members of the Bandelier Tuff; maximum exposed thickness about 40 m. *GRI Source Map ID 75592* (GM 79).

Qcs - Cerro Toledo Formation, Valle Toledo Member, Sierra de Toledo rhyolite (Pleistocene)

Flow-banded, sparsely porphyritic lava with phenocrysts of quartz, sanidine, biotite, and tiny magnetite; sanidine is typically chatoyant blue; possibly originates from two vents; 40Ar/39Ar ages of two samples range from 1.34 to 1.38 Ma (Spell et al. 1996); maximum exposed thickness is 365 m. *GRI Source Map ID 75592* (GM 79).

Qctr - Cerro Toledo Formation, Valle Toledo Member, Turkey Ridge rhyolite (Pleistocene)

Flow-banded, porphyritic lava with phenocrysts of quartz, sanidine, biotite, and magnetite; sanidine is commonly large and chatoyant; most samples are devitrified, platy, and spherulitic; has one vent along axis of ridge; 40Ar/39Ar age is 1.34 ± 0.02 Ma (Spell et al. 1996); maximum exposed thickness is 490 m. *GRI Source Map ID 75592* (GM 79).

Qcrm - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite (Pleistocene)

Large dome with thick flows and flow breccias of aphyric to sparsely porphyritic obsidian to white, devitrified lava; obsidian is a known source of artifacts (Steffen 2005); actual vent area is probably northwest of location shown on map; vent collapsed before or during formation of Valles caldera; small exposure of associated bedded tuff (Qcrmt) is southwest of dome; 40Ar/39Ar age is 1.428 ± 0.007 Ma (Kelley et al., in press); maximum exposed thickness about 410 m. *GRI Source Map ID 75592* (GM 79).

Qcrmt - Cerro Toledo Formation, Valle Toledo Member, Rabbit Mountain rhyolite, bedded tuff (Pleistocene)

Large dome with thick flows and flow breccias of aphyric to sparsely porphyritic obsidian to white, devitrified lava; obsidian is a known source of artifacts (Steffen 2005); actual vent area is probably northwest of location shown on map; vent collapsed before or during formation of Valles caldera; small exposure of associated bedded tuff (Qcrmt) is southwest of dome; 40Ar/39Ar age is 1.428 ± 0.007 Ma (Kelley et al., in press); maximum exposed thickness about 410 m. *GRI Source Map ID 75592* (GM 79).

Qnd - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte debris avalanche deposit (Pleistocene)

Qnd - Del Norte Pass debris avalanche deposit (Quaternary)
White to pale gray debris flows apparently formed by failure of Del Norte Pass rhyolite dome; forms irregular tongue of chaotic debris extending 4 km south-southeast from this dome, primarily south of a prominent ridge of biotite-hornblende dacite; consists of at least two pulses; surface of deposit is hummocky; deposit is matrix supported and matrix is extremely ashy; resembles avalanche deposits of Rabbit Mountain except that obsidian is much less abundant and large blocks of andesite and dacite are much more common; overlies Keres Group rocks near source; occurs between the Tshirege and Otowi Members of the Bandelier Tuff further from source; unit is locally so thick that overlying units of Qbt are absent; overlain by El Cajete pumice; maximum exposed thickness is about 60 m. *GRI Source Map ID 7225* (OF-GM 112).

Qnd - Paso del Norte debris avalanche deposit (Pleistocene)
Debris flows apparently formed by failure of Paso del Norte dome; forms irregular tongue of chaotic debris extending 4 km south-southeast; present between the Tshirege and Otowi Members of the Bandelier Tuff; maximum exposed thickness about 60 m. *GRI Source Map ID 75592* (GM 79).

Qct - Cerro Toledo Formation, Valle Toledo Member (Pleistocene)

Qct - Cerro Toledo rhyolite (Pleistocene)
Flow-banded, aphyric lava with microlites of quartz, sanidine, biotite; obsidian phase is completely aphyric and known source of artifacts (Steffen 2005); rarely contains spherulites and bread crust textures; overlies Indian Point rhyolite (Qci) and apparently underlies Turkey Ridge rhyolite (Qctr);

underlies Tshirege Member of the Bandelier Tuff (Qbt); originates from two vents; K-Ar age on Cerro Toledo proper is 1.38 ± 0.05 Ma (Stix et al. 1988); maximum exposed thickness is 520 m. *GRI Source Map ID 75592* (GM 79).

Qct - Cerro Toledo deposits (Pleistocene)
Tephra, reworked tephra and epiclastic alluvium deposited between eruptions of the Tshirege and Otowi members of the Bandelier Tuff (Broxton and Reneau, 1995). Alluvial deposits include sand, silt, and conglomerates with rounded clasts of Tschicoma lavas. Aphyric obsidian common. Fanglomerate alluvial deposits in Los Alamos Canyon record a major fluvial system during this interval. Tephras originated from rhyolite dome complex eruptions in the Toledo caldera and the Toledo embayment (Smith et al., 1970; Heiken et al., 1986). Tephra deposits typically contain pumices with rare phenocrysts of quartz, sanidine and biotite. In the northern portion of the map area crystal-rich tephras occur near the top of the interval, with abundant phenocrysts of quartz and sanidine. Radiometric ages of pumices and source domes range from 1.21 to 1.64 Ma (Izett et al., 1981; Stix et al., 1988; Spell et al., 1996). Maximum exposed thickness is ~ 100 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qct - Cerro Toledo interval (Quaternary)
Discontinuous interval of epiclastic sediments and tephras of mixed provenance that lie between the two members of the Bandelier Tuff (Broxton and Reneau, 1995); tuffaceous layers are part of the Cerro Toledo Rhyolite originating from sources in the Toledo caldera (Smith et al. 1970; Heiken et al., 1986); tuffaceous layers consist of rhyolitic pyroclastic fall deposits usually less than 2 m thick (Heiken et al., 1986; Stix et al., 1988); pumice clasts generally aphyric but contain rare phenocrysts of quartz, sanidine, and biotite; in northern map area, the sedimentary deposits consist of poorly sorted sand, gravel, and coarse-grained detritus of porphyritic dacite, andesite, and rare ignimbrite from sources to west, commonly intermixed with reworked rhyolitic pumice (Goff, 1995); in southern map area, the sedimentary deposits additionally include conspicuous aphyric obsidian fragments from debris avalanche west of map area (Goff et al., 1990); ages of tuffaceous units and source domes range from 1.21 to 1.64 Ma (Izett et al., 1981; Stix et al., 1988; Spell et al., 1996); maximum exposed thickness about 20 m but exceeds 30 m in several wells drilled on Pajarito Plateau. *GRI Source Map ID 7224* (OF-GM 42).

Qct - Source Name (lower Pleistocene)
Pumiceous alluvium and debris flows, bedded and channel cross-bedded gravel rich in subrounded dacitic clasts as large as 100 cm in diameter, and pumice-fall deposits separated by buried soils. Contains fragments of black, aphyric obsidian from an unknown source (Heiken and others, 1986); maximum observed thickness more than 35 m in the western map area. Overlies lower part of Bandelier Tuff in most exposures; overlain by upper part of Bandelier Tuff in the western map area; forms surface material near Santa Clara Canyon. Paleocurrent directions (azimuth) on channels and gravelly cross-beds range from 80° to 150°, and average about 110°. Gravel-rich sections of Qct locally crop out as ridges to rounded surfaces covered with dacitic clasts, particularly north of Chupaderos Canyon and in the western map area. Age 1.6–1.22 Ma (Spell and others, 1996). *GRI Source Map ID 6547* (MF 2419).

Qcep - Cerro Toledo Formation, Valle Toledo Member, East Los Posos rhyolite (Pleistocene)

Flow-banded to massive porphyritic lava with phenocrysts of quartz, sanidine, biotite, hornblende, opaque oxides; rarely contains black glassy groundmass; $^{40}Ar/^{39}Ar$ age is 1.45 ± 0.01 Ma (Spell et al. 1996); maximum exposed thickness about 60 m. *GRI Source Map ID 75592* (GM 79).

Qci - Cerro Toledo Formation, Valle Toledo Member, Indian Point rhyolite (Pleistocene)

Flow-banded, sparsely porphyritic lava with phenocrysts of quartz and sanidine; biotite is extremely rare; most samples are devitrified and spherulitic; $^{40}Ar/^{39}Ar$ age is 1.46 ± 0.01 Ma (Spell et al. 199); maximum exposed thickness is 410 m. *GRI Source Map ID 75592* (GM 79).

Qcnp - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite (Pleistocene)

Small dome and flow of devitrified rhyolite with sparse phenocrysts of quartz, sanidine, and biotite; layer of indurated, slightly altered, lithic-rich tuff (Qcnpt) underlies dome on east and southeast; 40Ar/39Ar age is 1.47 ± 0.04 Ma (Justet and Spell 201); maximum exposed thickness about 110 m. *GRI Source Map ID 75592* (GM 79).

Qcnpt - Cerro Toledo Formation, Valle Toledo Member, Paso del Norte rhyolite, lithic rich tuff (Pleistocene)

Small dome and flow (Qcnp) of devitrified rhyolite with sparse phenocrysts of quartz, sanidine, and biotite; layer of indurated, slightly altered, lithic-rich tuff underlies dome on east and southeast; 40Ar/39Ar age is 1.47 ± 0.04 Ma (Justet and Spell 201); maximum exposed thickness about 110 m. *GRI Source Map ID 75592* (GM 79).

Qcnr - Cerro Toledo Formation, Valle Toledo Member, north caldera rim intrusion (Pleistocene)

Flow-banded, sparsely porphyritic intrusive body and minor lava having phenocrysts of quartz, sanidine, and biotite; 40Ar/39Ar age is 1.61 ± 0.03 Ma (Kelley et al., in press); maximum exposed thickness is 50 m. *GRI Source Map ID 75592* (GM 79).

Qcwp - Cerro Toledo Formation, Valle Toledo Member, West Los Posos rhyolite (Pleistocene)

Flow-banded to massive porphyritic rhyolite with phenocrysts of quartz, sanidine, plagioclase, biotite, and opaque oxides; commonly contains relict black glass; $^{40}Ar/^{39}Ar$ ag is 1.54 ± 0.01 Ma (Spell et al. 1996); maximum exposed thickness 370 m. *GRI Source Map ID 75592* (GM 79).

Qbx - Bandelier Tuff, vent and/or hydrothermal breccia (Pleistocene)

Widely scattered, lenticular to nearly circular outcrops of mosaic or vent breccia, commonly located near or along faults and less than 300 m in diameter composed primarily of rounded to subrounded fragments of Bandelier Tuff (Qbt) in matrix of fine-grained tuff; may also contain abundant to rare fragments of precaldera rocks; may be hydrothermally altered; breccias of this type do not display gouge and shear fabric typical of fault breccia; thickness usually not measurable. *GRI Source Map ID 75592* (GM 79).

Qbt - Bandelier Tuff, Tshirege Member (Pleistocene)

Qbt - Upper Bandelier Tuff (Tshirege Member) (Quaternary)
White to orange to dark gray densely welded to non-welded rhyolitic, ash-flow tuff (ignimbrite); pumice and matrix contain abundant phenocrysts of sanidine and quartz, sparse microphenocrysts of black clinopyroxene and orthopyroxene and 25 extremely rare microphenocrysts of fayalite (Warshaw and Smith, 1988; Warren et al., 1997); sanidine typically displays blue iridescence; consists of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Gardner et al., 1986; Broxton and Reneau, 1995; Warren et al., 1997). Upper flow units generally more welded than lower ones. Locally displays a thin (<2 m) laminated, pumice fall (Tsankawi Pumice) and surge deposit at base of unit that contains roughly 1% of hornblende dacite pumice (Bailey et al., 1969) but this deposit is very thin or absent within map area. Locally contains accidental lithic fragments of older country rock entrained during venting and pyroclastic flow. Qbt forms upper surface of western Pajarito Plateau in central and southeastern map area; originated from catastrophic eruptions that formed Valles caldera. Most recent $^{40}Ar/^{39}Ar$ age is 1.25 ± 0.01 Ma (Phillips, 2004); maximum observed thickness is over 260 m in upper Frijoles Canyon. *GRI Source Map ID 7225* (OF-GM 112).

Qbt - Tshirege Member of Bandelier Tuff (early Pleistocene)
White to pink slightly welded pyroclastic flows and a thin (< 0.5 m) pumiceous fall unit, both of rhyolitic composition and containing abundant phenocrysts of chatoyant sanidine and quartz and trace clinopyroxene, hypersthene, and fayalite. Consists of two to five pyroclastic flows separated by pumice concentrations or thin, sorted partings, exposed along deep canyons west of the Rio Grande; thinner (<25 m) flow sections are preserved locally in shallow canyons east of the Rio Grande. Thickness generally <60 m, but locally >90 m along Medio Canyon. Paleoflow directions to the southeast. Overlies lower Bandelier Tuff or pumiceous piedmont alluvium of the Toledo interval. Derived from the Valles caldera area northwest of the map area. $^{40}Ar/^{39}Ar$ age is 1.22 ± 0.02 Ma (Izett and Obradovich, 1994). *GRI Source Map ID 7228* (SIM 3194).

Qbt - Bandelier Tuff, Tshirege Member (Pleistocene)
Multiple flows of densely welded to nonwelded rhyolitic ash-flow tuff erupted during formation of the Valles caldera (Smith and Bailey 1966, 1968); pumice and matrix contain abundant phenocrysts of sanidine and quartz, sparse microphenocrysts of clinopyroxene and orthopyroxene, and extremely rare microphenocrysts of fayalite (Warshaw and Smith 1988; Warren et al. 2007); in more welded portions, sanidine typically chatoyant (blue iridescence); contains accidental lithic fragments of older country rock; locally has a thin (<2 m) laminated, pumice-fall and surge deposit at base of unit (Tsankawi Pumice Bed) that contains roughly 1% of hornblende dacite pumice (Bailey et al. 1969); most recent $^{40}Ar/^{39}Ar$ age determination is 1.25 ± 0.01 Ma (Phillips et al. 2007); magnetic polarity reverse; maximum observed thickness within caldera more than 900 m. *GRI Source Map ID 75592* (GM 79).

Qbt - Upper Bandelier Tuff, Tshirege Member (Pleistocene)
Beige to orange to gray, poorly-welded to densely-welded ignimbrite containing abundant phenocrysts of sanidine and quartz and trace amounts of clinopyroxene and hypersthene (Smith and Bailey, 1966). Sanidine commonly displays blue iridescence. Accidental lithic fragments typically < 5% except in discreet lenses and lag horizons. Qbt is a compound flow unit with multiple flow units as described by Broxton and Reneau (1995) and Gardner et al. (1999, 2001), and is well exposed in canyons throughout the Pajarito Plateau. Surge deposits, typically < 1 meter thick, are common at the base of the unit and overlie a stratified pumice tephra (Tsankawi Pumice Bed) that is typically ~ 1 meter thick. The ignimbrite was erupted from the Valles caldera at 1.25 ± 0.01 Ma (Phillips, 2004) and filled valleys along the paleotopographically complex eastern flank of Sierra de Los Valles. The degree of welding decreases toward east and some of the upper cooling units pinch out toward the east. Maximum observed thickness is ~ 180 meters. *GRI Source Map ID 6633* (OF-GM 55).

Qbt - Tshirege Member of the Bandelier Tuff (lower Pleistocene)

Nonwelded to welded pyroclastic flows (Tshirege Member) and an underlying thin (<1 m) pumiceous fall unit (Tsankawi Pumice Bed), both of rhyolitic composition and derived from a powerful eruption associated with the Valles caldera. Common colors of white, gray, orange, and pink. The tuff contains 15-30% crystals of sanidine and quartz, rare microphenocrysts of black clinopyroxene and trace microphenocrysts of hypersthene (near the top) and fayalite (Broxton et al., 1995). Chatoyant sanidine is common within devitrified intervals of the deposit and anorthoclase is present in the upper part of the tuff. Hornblende-dacite pumice lapilli comprise less than 1 volume percent of the deposit and are most common in the earliest erupted ejecta, including the Tsankawi Pumice Bed (Stimac, 1996). Contains multiple flow units and at least four cooling units (Griggs, 1964; Bailey et al., 1969; Broxton et al., 1995). Dominates surfaces west of the Rio Grande and forms one prominent outcrop east of the Rio Grande (Section H of Dethier, 1997). As mapped, may include exposures of Otowi Member of Bandelier Tuff, which it lies above. Paleoflow direction to the east. Derived from the Valles caldera west of the map area. $^{40}Ar/^{39}Ar$ ages from single-crystal-sanidine range from 1.22-1.26 (Izett and Obradovich, 1994; Spell et al., 1996a, b; Phillips et al., 2007). Thickness is highly variable because of pre-existing topography. Thickness is generally 60 m or less, but locally is as much as 180 m. [Description slightly modified from Dethier, 1997, and Sawyer et al., in review]. *GRI Source Map ID 75477* (OFR 531).

Qbt - Upper Bandelier Tuff (Tshirege Member) (Quaternary)
White to orange to dark gray densely welded to non-welded rhyolitic, ash-flow tuff (ignimbrite); pumice and matrix contain abundant phenocrysts of sanidine and quartz, sparse microphenocrysts of black clinopyroxene and orthopyroxene and extremely rare microphenocrysts of fayalite (Warshaw and Smith, 1988; Warren et al., 1997); sanidine typically displays blue iridescence; consists of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Gardner et al., 1986; Broxton and Reneau, 1995; Warren et al., 1997). Upper flow units generally more welded than lower ones. Intracaldera flow units are highly welded with well-developed pumice fiamme and rare vitrophyre. Locally contains a thin (<2 m) laminated, pumice fall and surge deposit at base of unit (Tsankawi Pumice) that contains roughly 1% of hornblende dacite pumice (Bailey et al., 1969). Locally contains accidental lithic fragments of older country rock entrained during venting and pyroclastic flow. Qbt is major unit of the Valles caldera resurgent dome; forms inconspicuous canyon-filling outliers on pre-existing volcanic topography south of the caldera; originated from catastrophic eruptions that formed Valles caldera. Most recent $^{40}Ar/^{39}Ar$ age is 1.25 ± 0.01 Ma (Phillips, 2004); maximum observed thickness within caldera over 900 m. *GRI Source Map ID 7226* (OF-GM 111).

Qbt - Bandelier Tuff, Tshierge Member and Tsankawi Pumice Bed (lower Pleistocene)
White to tan to orange, non-welded to welded, rhyolite ash-flow tuff containing abundant (~15%) phenocrysts of quartz and sanidine, with quartz more abundant than sanidine, and trace clinopyroxene. Quartz phenocrysts are large (up to 3 mm) and euhedral. Sanidine is clear and commonly displays a blue iridescence. Locally contains abundant lithic clasts but typically lithic-poor (less than 2%). Compound cooling unit consisting of at least three flow units. Typically non-welded to slightly welded, but is densely welded locally. Basal pumice-fall deposit (Tsankawi Pumice Bed) occurs locally (less than 2 m thick). Forms conspicuous orange cliffs. Erupted ~1.22 Ma during Valles caldera formation. Maximum thickness ~150m. *GRI Source Map ID 7218* (OF-GM 85).

Qbt - Upper Bandelier Tuff (Tshirege Member) (Quaternary)
White to orange to pink welded to non-welded rhyolitic ash-flow tuff (ignimbrite) containing abundant phenocrysts of sanidine and quartz, rare microphenocrysts of black clinopyroxene and trace microphenocrysts of hypersthene and fayalite; sanidine typically displays a blue iridescence; consists of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Broxton and Reneau, 1995; Gardner et al., 2001); upper flow units are less voluminous and are generally confined to western map area; upper flow units generally more welded than lower ones; contains localized pyroclastic surge beds =1 m thick that generally become more abundant toward top of unit; locally contains a thin (=1m) laminated, pumice fall and surge deposit at base of unit (Tsankawi Pumice) that contains roughly 1% of hornblende dacite pumice (Bailey et al., 1969); locally contains accidental lithic fragments of older

country rock entrained during venting and pyroclastic flow; Qbt forms conspicuous orange to pink cliffs throughout the Pajarito Plateau; forms thick intracanyon deposit in gorge of ancestral Rio Grande upstream of Upper Falls, Frijoles Canyon (Reneau and Dethier, 1996; Reneau, 2000); originated from catastrophic eruptions that formed Valles caldera; $^{40}Ar/^{39}Ar$ age is 1.22 ± 0.01 Ma (Izett and Obradovich, 1994; Spell et al., 1996); maximum observed thickness in upper Frijoles Canyon greater than 260 m. *GRI Source Map ID 7224* (OF-GM 42).

Qbt - Bandelier Tuff, Tshierge Member (Quaternary)
White to beige non-welded to welded ash-flow tuff containing abundant phenocrysts of quartz and sanidine. Exposed primarily in the northwest corner of the quadrangle and as isolated outcrops in Paliza and Peralta canyons. Basal Tsankawi pumice only recognized in exposures along San Juan Canyon, overlain by multiple (at least 3) flow units. Erupted at approximately 1.22 Ma during the formation of the Valles Caldera (Spell et al., 1996). Maximum thickness is approximately 170 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qbt - Tshierge Member (lower Pleistocene)
White to pink slightly welded pyroclastic flows (upper part of Tsherige) and a thin (<0.5 m) pumiceous fall unit (Tsankawi Pumice Bed), all of rhyolitic composition and containing abundant phenocrysts of sanidine and quartz and trace clinopyroxene, hypersthene, and fayalite; sanidine typically displays blue iridescence. Consists of two or three pyroclastic flows separated by pumice concentrations or thin surge deposits. Thickness generally less than 40 m, but locally more than 50 m in the western map area. Dips less than 3° to the east, reflecting the buried paleoslope. Paleoflow directions are to the east and southeast, reflecting the volcanic source to the west and northwest. Derived from the Valles caldera west of the map area (Smith and others, 1970). $^{40}Ar/^{39}Ar$ age is 1.22 ± 0.02 Ma (Izett and Obradovich, 1994). *GRI Source Map ID 6547* (MF 2419).

Qxbo - Bandelier Tuff, caldera-collapse breccia, Bandelier Tuff, Otowi Member (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: silicified and brecciated Otowi Member of the Bandelier Tuff. *GRI Source Map ID 75592* (GM 79).

Qxt - Bandelier Tuff, caldera-collapse breccia, Tschicoma and Puye Formations (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Tschicoma Formation rhyodacite, dacite, and coarse volcaniclastic Puye Formation materials. *GRI Source Map ID 75592* (GM 79).

Qxpt - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation dacite tuff (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Paliza Canyon Formation dacite tuff. *GRI Source Map ID 75592* (GM 79).

Qxp - Bandelier Tuff, caldera-collapse breccia, Paliza Canyon Formation andesite and volcaniclastic materials (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Paliza Canyon Formation andesite and volcaniclastic materials. *GRI Source Map ID 75592* (GM 79).

Qxsf - Bandelier Tuff, caldera-collapse breccia, Santa Fe Group (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Santa Fe Group well-sorted Ojo Caliente Sandstone. *GRI Source Map ID 75592* (GM 79).

Qxr - Bandelier Tuff, caldera-collapse breccia, Ritito Formation (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Ritito Formation nonindurated sandstone and conglomerate locally rich in Precambrian cobbles and pebbles. *GRI Source Map ID 75592* (GM 79).

Qxa - Bandelier Tuff, caldera-collapse breccia, Abo Formation and Yeso Group (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Permian Abo Formation. *GRI Source Map ID 75592* (GM 79).

Qxm - Bandelier Tuff, caldera-collapse breccia, Madera Formation (Pleistocene)

Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman 1976); incorporated in and interbedded with intracaldera, upper and lower members of the Bandelier Tuff (Qbt and Qbo) (Goff et al. 2007); unit consists of: Pennsylvanian Madera Formation limestone, micrite, and shale. *GRI Source Map ID 75592* (GM 79).

Qbo - Bandelier Tuff, Otowi Member (Pleistocene)

Qbo - Lower Bandelier Tuff (Otowi Member) (Quaternary)
White to pale pink to orange, generally poorly welded, vitric rhyolitic ash-flow tuff; pumice and matrix contains abundant phenocrysts of sanidine and quartz, and sparse mafic microphenocrysts; sanidine may display a blue iridescence; contains abundant accidental lithic fragments (Eichelberger and Koch, 1979); consists of multiple flow units in a compound cooling unit; contains a stratified pumice fall (Guaje Pumice; Griggs, 1964) and surge deposit at its base that is very thin or absent in most of the Bland quadrangle; may form tent rocks; Qbo discontinuously fills in rugged topography on a volcanic surface of pre-Toledo caldera age; has been extensively to completely removed by erosion in upper Frijoles Canyon, Pines Canyon and lower Medio Dia Canyon; very difficult to distinguish from non-welded, vitric

portions of the upper Bandelier Tuff in hand samples and thin sections; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi Pumice or beneath intervening deposits of older gravel (Qog); originated from catastrophic eruptions that formed Toledo caldera; $^{40}Ar/^{39}Ar$ ages 1.61 ± 0.01 to 1.62 ± 0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996); samples of uppermost Otowi just below contacts with Rabbit Mountain and Del Norte Pass debris flow deposits are 1.58 to 1.70 Ma; maximum exposed thickness about 60 m. *GRI Source Map ID 7225* (OF-GM 112).

Qbo - Otowi Member of Bandelier Tuff (early Pleistocene)
White to pink, nonwelded rhyolitic ash-flow tuff and a laminated to poorly sorted compound pumiceous fall unit as thick as 10 m, both containing abundant phenocrysts of chatoyant sanidine, quartz and sparse mafic phenocrysts. The Otowi Member consists of one to three thick ash-flow units comprising a compound-cooling unit as thick as 30 m. Lithic fragments generally are more abundant than in unit Qbt. Best exposed south of Capulin Canyon and southwest of the Town of Cochiti Lake. Overlies 2 to 5 m of gray pumiceous alluvium (upper Cochiti Formation) in areas southwest of Lummis Canyon. Locally overlies axial gravel deposits (Qa1). Overlain by upper Bandelier Tuff, and andesitic flows. Derived from the Valles caldera northwest of the map area. $^{40}Ar/^{39}Ar$ age is 1.61 ± 0.01 Ma (Izett and Obradovich, 1994). *GRI Source Map ID 7228* (SIM 3194).

Qbo - Bandelier Tuff, Otowi Member (Pleistocene)
Poorly to densely welded rhyolitic ash-flow tuff; originated from catastrophic eruptions that formed Toledo caldera; pumice and matrix contain abundant phenocrysts of sanidine and quartz, and sparse mafic microphenocrysts; sanidine may display a blue iridescence; contains abundant accidental lithic fragments; basal Guaje Pumice Bed to east described by Bailey et al. (1969) not found in map area; $^{40}Ar/^{39}Ar$ ages 1.61 ± 0.01 to 1.62 ± 0.04 Ma (Izett and Obradovich 1994; Spell et al. 1996); magnetic polarity reverse; maximum exposed thickness about 120 m. *GRI Source Map ID 75592* (GM 79).

Qbo - Lower Bandelier Tuff, Otowi Member (Pleistocene)
White to beige poorly-welded ignimbrite with abundant phenocrysts of quartz and sanidine (Bailey et al., 1969). Abundant accidental lithic fragments of dark grey to red mafic rocks give outcrops a peppered appearance. Qbo is primarily a slope-forming unit and was erupted from the Toledo caldera at 1.61 ± 0.01 to 1.62 ± 0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996). Otowi Member ignimbrite was deposited primarily in the southeastern portion of the quadrangle and was not deposited north of Rendija Canyon. The Guaje Pumice Bed, a stratified pumice fall and surge deposit that preceded Otowi ignimbrite deposition, is exposed in isolated outcrops in Cabra Canyon (Qbog) and beneath the Otowi Member in Pueblo Canyon. The Guaje Pumice Bed, which is 2 - 3 m thick also crops out the contact between the Puye Formation and Cerro Toledo deposits in Guaje Canyon. Maximum exposed thickness is ~ 50 m. *GRI Source Map ID 6633* (OF-GM 55).

Qbo - Otowi Member of Bandelier Tuff (lower Pleistocene)
Slightly to non-welded pyroclastic flows (Otowi Member) of pumiceous rhyolite and an underlying compound, rhyolitic pumiceous fall unit (Guaje Member) as thick as 6 m, both derived from the Valles Caldera. Common colors of white, light gray, and orange. Consists of multiple flow units forming a single cooling unit (Smith and Bailey, 1966; Broxton et al., 1995). Generally contains more abundant accidental and accessory lithic fragments than the Tsirege Member. Contains 5-10% crystals composed almost entirely of sanidine and quartz with traces of clinopyroxene, plagioclase, and hornblende (Broxton et al., 1995). Sanidine is chatoyant within devitrified intervals of the tuff. Derived from the Valles caldera west of the map area. Lies beneath upper Bandelier Tuff. Single-crystal-sanidine $^{40}Ar/^{39}Ar$ age is 1.61-1.63 Ma (Izett and Obradovich, 1994; Spell et al., 1996a,b). Fills canyons as deep as 50 m cut into Cerros del Rio basalts, basaltic andesite, and phreatomagmatic deposits (collectively unit Tcv). Maximum thickness about 50 m (165 ft). [Description slightly modified from Dethier, 1997, and Sawyer et al., in review]. *GRI Source Map ID 75477* (OFR 531).

Qbo - Lower Bandelier Tuff (Otowi Member) (Quaternary)
White to pale pink to orange, generally poorly welded rhyolitic ash-flow tuff; pumice and matrix contains abundant phenocrysts of sanidine and quartz, and sparse mafic microphenocrysts; sanidine may display a blue iridescence; contains abundant accidental lithic fragments (Eichelberger and Koch, 1979); consists of multiple flow units in a compound cooling unit; contains a stratified pumice fall and surge deposit at its base (Guaje Pumice; Griggs, 1964); may form tent rocks; Qbo discontinuously fills in rugged topography on a volcanic surface of pre-Toledo caldera age; forms broad plateau covered with Qvec southwest of the caldera margin; very difficult to distinguish from upper Bandelier Tuff in hand samples and thin sections; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi Pumice; originated from catastrophic eruptions that formed Toledo caldera; $^{40}Ar/^{39}Ar$ ages 1.61 ± 0.01 to 1.62 ± 0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996); maximum exposed thickness about 60 m. *GRI Source Map ID 7226* (OF-GM 111).

Qbo - Bandelier Tuff, Otowi Member and Guaje Pumice Bed (Lower Pleistocene)
White to tan nonwelded rhyolite ash-flow tuff containing abundant (~10-15%) phenocrysts of euhedral quartz (3 mm) and sanidine, with more quartz than sanidine, and trace mafic phenocrysts. Commonly contains abundant (3-10%) mafic lithic clasts. Basal pumice-fall deposit (Guaje Pumice Bed) occurs locally (less than 2 m thick). Typically forms slopes, and tent rock formation is also common. Erupted ~1.61 Ma during the Toledo caldera formation. Maximum thickness ~100 m. *GRI Source Map ID 7218* (OF-GM 85).

Qbo - Lower Bandelier Tuff (Otowi Member) (Quaternary)
White to pale pink, generally poorly welded rhyolitic ash-flow tuff containing abundant phenocrysts of sanidine and quartz, and sparse mafic phenocrysts; sanidine may display a blue iridescence; contains abundant accidental lithic fragments; consists of multiple flow units in a compound cooling unit; contains a stratified pumice fall and surge deposit at base of unit (Guaje Pumice); may form tent rocks; Qbo discontinuously fills in rugged topography on a pre-Toledo caldera age volcanic surface; upper surface undulatory due to erosion; very difficult to distinguish from upper Bandelier Tuff in hand samples; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi Pumice and/or Cerro Toledo interval; originated from catastrophic eruptions that formed Toledo caldera; $^{40}Ar/^{39}Ar$ ages 1.61 ± 0.01 to 1.62 ± 0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996); maximum exposed thickness about 75 m. *GRI Source Map ID 7224* (OF-GM 42).

Qbo - Bandelier Tuff, Otowi Member (Quaternary)
White to beige non-welded ash-flow tuff containing abundant phenocrysts of quartz and sanidine and sparse mafic phenocrysts. Moderate to abundant lithic fragments, primarily of andesitic or mafic lavas. This unit is best exposed in the northwest corner of the quadrangle where it filled a large paleocanyon, later reincised to form the modern San Juan Canyon. Isolated exposures also occur in Peralta Canyon where capped (preserved) by the Tshirege Member. Erupted at approximately 1.61 Ma during the formation of the Toledo Caldera (Spell et al., 1996). Maximum thickness is approximately 70 meters. *GRI Source Map ID 6630* (OF-GM 74).

Qbo - Upper part of Otowi Member (early Pleistocene)
White to pink, unwelded rhyolitic ash-flows containing abundant phenocrysts of sanidine and quartz, sparse mafic phenocrysts and locally abundant lithic fragments. Consists of one to three thick flow units in a compound cooling unit as thick as 40 m. Best exposed in pumice mines north of Guaje Canyon and south of access road to Puye site. Overlies Guaje Pumice Bed and Puye Formation. Overlain by pumiceous alluvium of the Cerro Toledo interval (Qct) or upper part of Bandelier Tuff. Poorly exposed or buried by colluvium where these units are absent. Derived from the Valles caldera west of the map area. $^{40}Ar/^{39}Ar$ age is 1.61 ± 0.01 Ma (Izett and Obradovich, 1994). *GRI Source Map ID 6547* (MF 2419).

Qbog - Bandelier Tuff, Guaje Pumice Bed (Pleistocene)

Qbog - Guaje Pumice Bed (Pleistocene)
Stratified pumice fall and surge deposit that preceded Otowi ignimbrite deposition; exposed in isolated outcrops in Cabra Canyon and beneath the Otowi Member in Pueblo Canyon. The Guaje Pumice Bed, which is 2 - 3 m thick also crops out the contact between the Puye Formation and Cerro Toledo deposits in Guaje Canyon. *GRI Source Map ID 6633* (OF-GM 55).

Qbg - Source Name (early Pleistocene)
White to pink, unwelded rhyolitic ash-flows containing abundant phenocrysts of sanidine and quartz, sparse mafic phenocrysts and locally abundant lithic fragments. Consists of one to three thick flow units in a compound cooling unit as thick as 40 m. Best exposed in pumice mines north of Guaje Canyon and south of access road to Puye site. Overlies Guaje Pumice Bed and Puye Formation. Overlain by pumiceous alluvium of the Cerro Toledo interval (Qct) or upper part of Bandelier Tuff. Poorly exposed or buried by colluvium where these units are absent. Derived from the Valles caldera west of the map area. $^{40}Ar/^{39}Ar$ age is 1.61 ± 0.01 Ma (Izett and Obradovich, 1994). *GRI Source Map ID 6547* (MF 2419).

Qgo - Bandelier Tuff, older gravels (Pleistocene)

Qgo - Older gravels (Quaternary)
Sediments interbedded with the upper and lower Bandelier Tuff south and east of the caldera margin; consists primarily of dark gray to buff gravel, fluvial and minor debris flow deposits; clasts consist of precaldera volcanic rocks, aphyric obsidian attributed to Rabbit Mountain or Del Norte Pass domes, and welded to silicified Bandelier Tuff; exposures are often poor; without stratigraphic or spatial control, unit is difficult to distinguish from Tpv or Qdf (cross section only) if no Bandelier Tuff or obsidian clasts are present; maximum exposed thickness is 25 m. *GRI Source Map ID 7225* (OF-GM 112).

Qgo - Older gravels (Pleistocene)
Fluvial sandstone and gravel deposited beneath the Otowi Member or between the Otowi and La Cueva Members of the Bandelier Tuff; gravel clasts composed predominantly of Paliza Canyon volcanic rocks with local Proterozoic granite, Permian sandstone and conglomerate, and rare Oligocene to Miocene Pedernal chert; maximum thickness 7 m. *GRI Source Map ID 75592* (GM 79).

Qog - Older gravels (Quaternary)
Dark gray to buff gravel and debris flow deposits interbedded with the upper Bandelier Tuff south of the caldera margin; consists primarily of precaldera volcanic rocks and Bandelier Tuff; exposures are small and usually poor; without stratigraphic control, unit is difficult to distinguish from Tpv if no Bandelier Tuff clasts are present; maximum exposed thickness is 25 m. *GRI Source Map ID 7226* (OF-GM 111).

Qt3 - Terrace gravel, correlative with Santo Domingo Pueblo terraces (middle Pleistocene)

Fill-terrace gravel 5-10 m thick, with an upper surface approximately 30-35 m above grade. Terraces probably correlate to similarly numbered terrace deposits along the Rio Grande in the Santo Domingo Pueblo quadrangle (Smith and Kuhle, 1998). The Rio Grande terraces likely correlate to those for which Dethier and McCoy (1993) estimate an age of 170 ± 40 ka. *GRI Source Map ID 7218* (OF-GM 85).

Qt2 - Terrace gravel, correlative with Canada terrace of Aby (1997) (middle Pleistocene)

Fill-terrace gravel, 5-10 m thick, located approximately 50-70 m above grade. The correlative terraces along the Rio Grande on the Santo Domingo Pueblo quadrangle are less than 550 ka (Smith and Kuhle, 1998) and are tentatively correlated to Española Basin terraces for which Dethier and McCoy (1993) estimate an age of 310 ± 70 ka. Qt2 is probably correlative with the Cañada terrace of Aby (1997). *GRI Source Map ID 7218* (OF-GM 85).

Qt1 - Terrace gravel, former courses of Peralta and Cochiti Canyons (middle Pleistocene)

Fill-terrace gravel, generally 3-5 m thick, but locally as much as 20 m thick, marking former courses of Peralta and Cochiti Canyons. This gravel deposit commonly forms inverted ridges rather than being inset along modern drainages and, therefore, is technically not a terrace deposit, but is mapped as a terrace deposit to be consistent with designation of presumed correlative gravel. Terrace gravel in a similar landscape position on the Santo Domingo Pueblo Southwest quadrangle contains the 620 ka Lava Creek B ash (Smith and Kuhle, 1997b). *GRI Source Map ID 7218* (OF-GM 85).

Qa3 - Alluvial deposit, boulder gravel and cross-bedded sand (middle Pleistocene)

Qa3 - Alluvial deposit 3 (middle Pleistocene)
Well-sorted cobble to poorly sorted boulder gravel, cross-bedded sand, and thin-bedded sand beneath terrace remnants 25–45 m above the Rio Grande, preserved at mouths of tributaries and in an extensive deposit near Alamo Canyon that contain angular boulders as large as 3.5 m. Clasts are predominantly axial river lithologies but are locally rich in andesitic and dacitic rocks derived from volcanic terrane to the west. Overlies and truncates rocks of the Santa Fe Group, landslide deposits, older alluvium or hydromagmatic deposits. Extensive deposits on both sides of Rio Grande near the mouth of Alamo Canyon are overlain by El Cajete tephra. Soils 0.5–1.0 m thick contain Stage II or Stage III carbonate morphology and local buried Bt horizons. Thickness 4–15 m. *GRI Source Map ID 7228* (SIM 3194).

Qst - Stream terrace deposits (Pleistocene)
Sand and gravel that underlie a suite of terraces above active drainages and associated valley-floor deposits, and below QTst and Tgt terrace deposits. Some thick fill-terraces are dominated by clayey-silty very fine- to medium-grained sand and overlie a strath with pronounced relief. The lower contact between these deposits and the underlying Tesuque Formation is marked by an angular unconformity and scour. In a longitudinal profile, it is common for straths to diverge in a downstream direction. At least four terrace levels are present, ranging from 3 to 65 m above modern stream grade. Sand and clay-silt exhibit colors of light-yellowish-brown (10YR 6/4), very pale brown (10YR 7/4), light-brown (7.5YR 6/4), pink (7.5YR 7/4), reddish-yellow (7.5YR 6-7/6), pale brown (10YR 6/3), yellowish brown (10YR 5/4), or strong brown (7.5YR 5/6). Beds are very thin to medium, and commonly lenticular or concave-up, ribbon-shaped. Gravel is clast-supported, moderately to poorly sorted, and generally composed of cobbles and pebbles with <5% boulders (boulders are more common within or near the Sangre de Cristo Mountains). Clast composition is mostly granite to granitic gneiss, with very minor amphibolite, schist, Paleozoic siltstone-sandstone, gneiss, and quartzite. Quartzite clasts are well-rounded to subrounded; for other rock types, cobbles are rounded to subrounded, coarse to very coarse pebbles are rounded to subangular, and very fine to medium pebbles are angular to subrounded. Clasts are generally larger and more rounded in a given terrace deposit compared to underlying Santa Fe Group strata (if present). Sand is very fine- to very coarse-grained (mostly medium- to very coarse-grained), moderately to poorly sorted, subrounded to subangular, and arkosic. Two radiocarbon dates for two relatively low-level fill terraces along the Santa Fe River returned ages of 7 ka and 10 ka (Read et al., 1999). Higher level fill terraces

along the Rio Tesuque and south of the Pojoaque River may be correlated to the terrace stratigraphy developed along the Rio Grande by Dethier and Reneau (1995) (e.g., Koning and Maldonado, 2001). Sediment is unconsolidated and up to 18 m-thick (generally less than 8 m-thick). *GRI Source Map ID 75477* (OFR 531).

Qal3 - Alluvial deposits (middle(?) Pleistocene)
Well-sorted cobble to poorly sorted boulder gravel and cross-bedded sand beneath terrace remnants 25–45 m above Rio Grande, preserved at the mouth of Los Alamos Canyon. Clasts predominantly axial-river types (see General notes); locally rich in dacitic rocks derived from the Jemez Mountains. Thickness ranges from 4 to more than 15 m. Overlies and truncates rocks of the Santa Fe Group or landslide deposits. Soils 0.5–1.0 m thick contain Stage II or Stage III carbonate morphology (Birkeland, 1999) and local buried Bt horizons. *GRI Source Map ID 6547* (MF 2419).

Qp3 - Piedmont alluvial deposit, poorly sorted gravel and sand (middle Pleistocene)

Qp3 - Piedmont alluvial deposit 3 (middle Pleistocene)
Poorly sorted cobble to boulder gravel and sand. West of the Rio Grande, clasts are predominantly andesite and silicic tuff derived from the west and the matrix is rich in lithic fragments and quartz. East of the Rio Grande granitic and metamorphic clasts predominate and matrix is arkosic. Overlies Cochiti Formation, Otowi Member of the Bandelier Tuff, or Santa Fe Group deposits. Extensive exposures are preserved north of Bland Canyon. Soils are 0.5–1.0 m thick with Stage II or Stage III carbonate morphology; strongly developed Bt horizons locally are buried by El Cajete tephra. Deposits 0.5–8.0 m thick are exposed beneath terraces 25–40 m above present channels graded to the Rio Grande. *GRI Source Map ID 7228* (SIM 3194).

Qtp3 - Piedmont alluvium (middle(?) Pleistocene)
Poorly to moderately well sorted cobble to boulder gravel and sand. Clasts predominantly dacite mixed locally with quartzite and other resistant gravel derived from northern sources; matrix rich in dacite fragments and quartz. Deposits mainly 0.5–1.5 m thick, locally as thick as 20 m; exposed beneath terraces 30–40 m above present drainages graded to the Rio Grande. Overlies Santa Fe Group or Puye Formation. Best exposed between Chupaderos and Santa Clara Canyons. Soils 0.5–1.0 m thick contain Stage II or Stage III carbonate (Birkeland, 1999) and locally strongly developed Bt horizons. *GRI Source Map ID 6547* (MF 2419).

Qa2 - Alluvial deposit, cobble and boulder gravel (middle? Pleistocene)

Well-sorted cobble to boulder gravel containing layers composed of boulders as large as 3 m, exposed beneath terrace remnants approximately 50 to 70 m above the Rio Grande. Contact relations best exposed on both sides of Cochiti Lake, south and southwest of the Tetilla Peak overlook, where 8–25 m of gravelly axial channel deposits overlie lower Pleistocene and Pliocene cobble gravel of the Santa Fe Group; axial facies. These deposits contain laterally extensive boulder layers. Sandy to silt rich piedmont alluvium 2–8 m thick derived from eastern sources and layers of angular boulders of basalt interfinger with and overlie the axial alluvium in the southeastern part of map area. Overlies Santa Fe Group or landslide deposits. Deposits contain clasts of upper Bandelier Tuff and a local bed of ~0.55 Ma tephra derived from Valles caldera. Amino-acid ratios from gastropods in the upper 5 m of the deposits suggest a local age of 250 to 300 ka (see Dethier and McCoy, 1993). Deposits are overlain by El Cajete tephra (~55 ka; Reneau and others, 1996) and may be in part coeval with unit Qa1. Soils are 0.8–1.5 m thick and contain Stage IV carbonate in gravel; finer piedmont deposits expose several buried Bt horizons locally and carbonate development is Stage III. Thickness generally 10–30 m. *GRI Source Map ID 7228* (SIM 3194).

Qp2 - Piedmont alluvial deposit, gravel, silt and massive sand (middle? Pleistocene)

Qp2 - Piedmont alluvium (middle? Pleistocene)
Poorly sorted cobble to boulder gravel and massive sand and local silt beds in the southeast part of the map area beneath terrace remnants 45–60 m above present channels. West of the Rio Grande, clasts are predominantly andesite and silicic tuff derived from sources in the Jemez Mountains west of the map area and the matrix is rich in lithic fragments and quartz. East of the Rio Grande, clasts are mainly granitic and metamorphic clasts and matrix is arkosic. Overlies Cochiti Formation, lower Bandelier Tuff, or deposits of the Santa Fe Group. Extensive exposures west of Santa Cruz Arroyo are interfingered with middle(?) Pleistocene alluvial deposits (Qa2) and include several carbonate horizons with Stage II or Stage III carbonate morphology and locally strongly developed buried Bt horizons. *GRI Source Map ID 7228* (SIM 3194).

Qtp2 - Piedmont alluvium (middle Pleistocene)
Poorly sorted cobble to boulder gravel in deposits 0.5–3 m thick beneath isolated terrace remnants 45–60 m above present channels. Clasts predominantly dacite. Overlies Santa Fe Group near the intersection of Guaje and Los Alamos Canyons and Puye Formation at isolated exposures in Santa Clara Canyon. Soils poorly exposed, but locally contain Stage III+ carbonate (Birkeland, 1999). *GRI Source Map ID 6547* (MF 2419).

Qa1 - Alluvial deposit, cobble and boulder gravel with beds of coarse sand (early Pleistocene)

Poorly sorted boulder gravel containing clasts of volcanic rock as large as 4 m, well-sorted cobble gravel and beds of coarse sand exposed beneath terrace remnants 80–130 m above the Rio Grande south of the mouth of Capulin Canyon. Boulder-rich beds contain abundant clasts of andesite and welded Bandelier Tuff and minor basalt or axial-river lithologies derived from sources northwest of the modern river. Most exposures contain boulders of, and are thus younger than, the 1.22 Ma Tshirege Member of the Bandelier Tuff (Izett and Obradovich, 1994); basal exposures at several sites contain no axial lithologies and fill narrow paleodrainages cut into the Tshirege Member of the Bandelier Tuff. Deposits SE of the Town of Cochiti Lake contain boulders of the 1.61 Ma Otowi Member of the Bandelier Tuff (Izett and Obradovich, 1994). Deposits overlie basaltic or andesitic rocks in most areas. Overlain by eolian deposits, El Cajete tephra, and locally derived alluvium. Soils are 1.0 to > 2.0 m thick; finer overlying piedmont deposits expose multiple buried Bt horizons locally. Carbonate development is Stage III+ or Stage IV; carbonate-rich horizons locally brecciated and broken by vertical veins. Deposits at several sites between Alamo Canyon and Sanchez Canyon fill narrow paleocanyons cut before deposition of lower Bandelier Tuff (Reneau and Dethier, 1996). Locally overlain by upper Bandelier Tuff. Thickness generally 10–30 m, but thicker near the mouth of Medio Canyon. *GRI Source Map ID 7228* (SIM 3194).

Qp1 - Piedmont alluvial deposit, gravel (early? Pleistocene)

Qp1 - Piedmont alluvium (early? Pleistocene)
Poorly sorted cobble to boulder gravel forming terrace remnants >60 m above present channels. Clasts rich in andesite and silicic tuff derived from sources in the Jemez Mountains. Overlies Cochiti Formation or Otowi Member of the Bandelier Tuff. Near the Town of Cochiti Lake, deposits overlie or grade laterally into deposits of unit Qa1. Poorly exposed. *GRI Source Map ID 7228* (SIM 3194).

Qtp1 - Piedmont alluvium (middle to lower(?) Pleistocene)
Poorly sorted cobble to boulder gravel, sand, and local eolian silty sand beneath terrace remnants at several levels between 60 and about 100 m above present channels. Clasts predominantly dacite. Deposits mainly 1–10 m thick, but poorly exposed. Overlies and locally includes areas of Puye

Formation too small to show at this map scale. Mapped mainly north of Guaje Canyon. *GRI Source Map ID 6547* (MF 2419).

Qba - Basaltic alluvium (early? to middle? Pleistocene)

Several poorly exposed deposits of locally bouldery, cobbly and pebbly gravel with a sandy matrix and pebbly sand are exposed near the eastern boundary of the map area. Clasts are commonly subangular and consist of basalt, basaltic andesite, and andesite. The unit locally contains carbonate-cemented lenses composed of pumice fragments about 2 mm to 10 cm in diameter. This pumice was probably derived from the nearby Jemez Mountains. Likely sources of the pumice are the 1.22 Ma Tsankawi Pumice Bed of the Tshirege Member of the Bandelier Tuff, and the 1.61 Ma Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Bailey and others, 1969; Izett and Obradovich, 1994). Unit Qba is mostly stream alluvium, but also probably includes fan alluvium and debris-flow deposits as well as sheetwash deposits. Unit Qba is equivalent to the alluvium on basalt of Spiegel and Baldwin (1963). Thickness possibly about 3–10 m. *GRI Source Map ID 75593* (SIM 3179).

Qcuc - Andesite of Cochiti Volcano, upper unit, cinder deposits (early Pleistocene)

Qcuc - Andesite of Cochiti Volcano, upper unit, cinder deposits (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti volcano near the southwestern boundary of the map area. Cochiti volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Consists of an upper (Qcu) and lower (Qcl) sequence of preserved lava flows and near vent pyroclastic material (Qcuc) associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti volcano in on the eastern margin of the map area. Maximum exposed thickness is 350 m. Near-vent pyroclastic deposits, predominantly scoria and spatter agglutinate and minor flow material. Deposits are only present along the eastern edge of the map area. *GRI Source Map ID 7228* (SIM 3194).

Qcuc - Andesite of Cochiti Volcano, upper unit, cinder deposits (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti Volcano, which is on the Cochiti Dam quadrangle, near the southwestern boundary of the map area. Cochiti Volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Unit consists of an upper and lower sequence of preserved lava flows and near vent pyroclastic material associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti Volcano. Maximum exposed thickness is 40 m, but deposits thicken dramatically to the west in the adjacent quadrangle. Near-vent pyroclastic deposits, predominantly scoria and spatter agglutinate and minor flow material. Deposits are only present along the western edge of the map area. *GRI Source Map ID 75593* (SIM 3179).

Qcu - Andesite of Cochiti Volcano, upper unit, lava flows (early Pleistocene)

Qcu - Andesite of Cochiti Volcano, upper unit, lava flows (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti volcano near the southwestern boundary of the map area. Cochiti volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Consists of an upper (Qcu) and lower (Qcl) sequence of preserved lava flows and near vent pyroclastic material (Qcuc) associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti volcano in on the eastern margin of the map area. Maximum exposed thickness is 350 m. Medium to dark gray andesite lava flows (59–62 weight percent SiO_2); typically thin

(3–5 m), platy and discontinuous and are everywhere overlain by near-vent deposits, predominantly cinder and lesser amounts of spatter. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance. An $^{40}Ar/^{39}Ar$ isotopic age of 1.51 ± 0.05 Ma was obtained from a lava flow near the base of the section on the northwest side of Cochiti volcano (sample 3MRG3). These flows have reverse aeromagnetic and paleomagnetic signature. *GRI Source Map ID 7228* (SIM 3194).

Qcu - Andesite of Cochiti Volcano, upper unit, lava flows (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti Volcano, which is on the Cochiti Dam quadrangle, near the southwestern boundary of the map area. Cochiti Volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Unit consists of an upper and lower sequence of preserved lava flows and near vent pyroclastic material associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti Volcano. Maximum exposed thickness is 40 m, but deposits thicken dramatically to the west in the adjacent quadrangle. Medium to dark gray andesite lava flows (59–62 weight percent SiO_2); typically thin (3–5 m), platy and discontinuous and are everywhere overlain by near-vent deposits, predominantly cinder and lesser amounts of spatter. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance. An $^{40}Ar/^{39}Ar$ isotopic age of 1.51 ± 0.05 Ma was obtained from a lava flow near the base of the section on the northwest side of Cochiti Cone in the adjacent Cochiti Dam quadrangle. These flows have reverse aeromagnetic and paleomagnectic signature. *GRI Source Map ID 75593* (SIM 3179).

Andesite of Little Cochiti cone (early Pleistocene)

Reddish brown to medium gray andesite (58–60 weight percent SiO_2) lava flows (Qlc) and associated pyroclastic deposits (Qlcc) erupted from small volcanic cone in the southeastern part of the map area herein referred to as Little Cochiti cone. Little Cochiti cone deposits post-date down-to-west offset along the La Bajada fault, whose footwall formed a topographic escarpment over which westward flowing lava cascaded toward the present day course of the Rio Grande. Subsequent down-to-west offset along the La Bajada fault may have accentuated the offset of deposits preserved on the hanging wall and footwall blocks. Basal lava flows are typically thin (3–5 m), platy and discontinuous. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance, xenocrysts of plagioclase and lesser quartz are common near the vent area centered about hill 6598' on the Caja del Rio. Maximum exposed thickness is 70 m.

Qlcc - cinder deposits (early Pleistocene)

Near-vent pyroclastic deposits, predominantly scoria and spatter agglutinate and minor flow material, present only in proximity to eroded vent area. *GRI Source Map ID 7228* (SIM 3194).

Qlc - lava flows (early Pleistocene)

Medium to dark gray andesite lava flows; typically thin (3–5 m), platy and discontinuous and are everywhere overlain by near-vent deposits, predominantly cinder and lesser amounts of spatter. An $^{40}Ar/^{39}Ar$ isotopic age of 1.14 ± 0.13 Ma was obtained from a lava flow near the head of Santa Cruz Arroyo (sample 96TCD08). Lava flows have reversed aeromagnetic signature and reverse magnetic polarity based on magnetic fluxgate determinations. *GRI Source Map ID 7228* (SIM 3194).

Qd - Dacite of Arroyo Montoso (early Pleistocene)

Dark gray to black, fine grained to glassy, aphyric dacite lava flows and dome remnants (64–65 weight percent SiO_2) best exposed near the confluence of the Rio Grande and Arroyo Montoso. Lava flows are thick (up to 20 m) and massive with brecciated flow bases and flow foliated tops. Sparse phenocrysts of olivine ± pyroxene ± plagioclase occur locally in a microcrystalline to cryptocrystalline groundmass. Partially resorbed xenocrysts of plagioclase ± quartz are sparse but ubiquitous. An $^{40}Ar/^{39}Ar$ isotopic age of 1.31 ± 0.08 Ma was obtained from a lava flow above the Rio Grande (sample DN85113). Locally overlies deposits of unit Qbo. Maximum exposed thickness is 170 m. *GRI Source Map ID 7228* (SIM 3194).

Qcl - Andesite of Cochiti Volcano, lower unit (early Pleistocene)

Qcl - Andesite of Cochiti Volcano, lower unit (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti volcano near the southwestern boundary of the map area. Cochiti volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Consists of an upper (Qcu) and lower (Qcl) sequence of preserved lava flows and near vent pyroclastic material (Qcuc) associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti volcano in on the eastern margin of the map area. Maximum exposed thickness is 350 m Upper unit, cinder deposits—Near-vent pyroclastic deposits, predominantly. *GRI Source Map ID 7228* (SIM 3194).

Qcl - Andesite of Cochiti Volcano, lower unit (early Pleistocene)
Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti Volcano, which is on the Cochiti Dam quadrangle, near the southwestern boundary of the map area. Cochiti Volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Unit consists of an upper and lower sequence of preserved lava flows and near vent pyroclastic material associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti Volcano. Maximum exposed thickness is 40 m, but deposits thicken dramatically to the west in the adjacent quadrangle. Medium to dark gray andesite lava flows (53–59 weight percent SiO_2), typically thin, less than 3 m in map area but locally thicken in adjacent Cochiti Dam quadrangle. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance; slightly higher proportions of olivine than in Qcu. Flows are interpreted to have reversed magnetic polarity based on aeromagnetic signature. Poorly exposed, maximum thickness 40 m, base not exposed. *GRI Source Map ID 75593* (SIM 3179).

Qacl - Basaltic andesite of Cochiti Lake (early Pleistocene)

Medium- to dark-gray, basaltic andesite (54 weight percent SiO_2) lava flows, typically 2–4 meters thick exposed along the Rio Grande near the southern edge of the map area. Sparsely phyric containing phenocrysts of olivine±pyroxene. An $^{40}Ar/^{39}Ar$ isotopic age of 2.52 ± 0.04 Ma (sample DN9612) was obtained from a lava flow on the west bank of the Rio Grande southeast of the community of Cochiti Lake. Flows are interpreted to have reversed magnetic polarity based on aeromagnetic signature. Maximum thickness 25 m. *GRI Source Map ID 7228* (SIM 3194).

QTtp - Piedmont alluvium (early Pleistocene(?) and late Pliocene)

Poorly to moderately sorted dacitic cobble gravel and beds of coarse sand and boulder-rich debris-flow deposits interbedded with eolian fine sand and silt. Basal deposits include subrounded dacitic boulders in many exposures; matrix rich in dacitic clasts, quartz, and feldspar. Preserved on mesa surfaces more

than 100 m above present grade. Thickness mainly 2–12 m. Base generally not exposed, but overlies the upper lacustrine facies of the Puye Formation (Tpl) from Guaje Canyon to north of Santa Clara Canyon; may locally overlie lower part of Bandelier Tuff at some sites. Includes areas of Puye Formation too small to show at this map scale. Soils poorly exposed but locally contain Stage IV carbonate (Birkeland, 1999). *GRI Source Map ID 6547* (MF 2419).

QTcrv - Cerros del Rio volcanic rocks (lower Pleistocene to upper Pliocene)

Basalt, basaltic andesite, and andesite lava flows and associated phreatomagmatic deposits that cap the Caja del Rio Plateau. Central-vent volcanoes typify the eruptive centers in this field, and range from low-relief shields to steep-sided, breached cinder cones (Thompson et al., 2006). SiO_2 conent ranges from 48 to 65 wt percent (mostly 48-60%; Thompson et al., 2006). Low silica, subalkaline basaltic lavas were generally erupted from broad shield volcanoes, are relatively thin (<3-4 m), and had long travel distances (Thompson et al., 2006). The basalt flows are medium- to dark-gray and generally contain olivine and clinopyroxene phenocrysts in a fine-grained groundmass (Koning and Maldonaldo, 2001; Shroba et al., 2005; Koning and Hallett, 2000). Flows may display flow banding as well as varying degrees of vesiculation. The higher silica lavas (basaltic andesite and andesite) were erupted from high-relief, steep-sided vents, are thicker (as much as 30 m), and more discontinuous (Thompson et al., 2006). Basaltic andesite flows are medium-dark-gray with olivine phenocrysts in a fine- to medium-grained groundmass. They look similar to the basalt flows but are thicker and the lower part of the flows is platy (Koning and Maldonaldo, 2001). Andesite flows are brownish-gray to medium-gray and occasionally flow banded (Koning and Maldonaldo, 2001). These contain ubiquitous phenocrysts of hornblende, plagioclase, clinopyroxene, Fe-Ti oxides, and minor olivine in a fine- to medium-grained groundmass (Shroba et al., 2005). Their flows are commonly massive and blocky (Shroba et al, 2005). Phreatomagmatic deposits and lapilli generally underlie the package of aforementioned flows. They are exposed along the eastern edge of the Caja del Rio Plateau, but are also found interbedded within the Ancha Formation. Primary ejecta lapilli is black and in very thin, planar to wavy, even beds or laminations. The phreatomagmatic deposits are composed of pale brown to very pale brown silty sand with 3-20% pebbles. The age of the volcanic rocks range from 2.7 to 1 Ma, with most rocks being 2.7-2.2 Ma (early to middle phase of Thompson et al., 2006). Thickness of the volcanic pile ranges from a few meters along the eastern margin to 100-240 m in the central part of the Caja del Rio Plateau [Description taken from Thompson et al., 2006]. *GRI Source Map ID 75477* (OFR 531).

QTbt - Basaltic tephra (lower Pleistocene to upper Pliocene)

Interbedded basaltic lapilli (both primary and reworked magmatic ejecta) and phreatomagmatic sediments that underlie Cerros del Rio volcanic flows and overlie the Ancha and Tesuque formations. This unit locally includes subordinate beds of the Ancha Formation. Surge-and-fall deposits are moderately sorted and contain subangular to subrounded volcanic lapilli composed of basalt and basaltic andesite, ash, and cinders. Basaltic lapilli from surge-and-fall deposits is in very thin, planar to wavy, even, distinct, well to moderately sorted, and clast-supported beds or laminations. This lapilli is black (5Y 2.5/1) and clast size is mostly 0.5-15 mm. Welding of adjacent lapilli is observed in primary magmatic ejecta. Bombs, up to 25 cm long, have formed impact-related depressions on the underlying sediment. Most deposits of this unit are reworked from primary ashfall (tephra) deposits and contain various amounts of sand-size quartz, feldspar, and locally scattered granite and siltstone clasts less than about 4 cm in diameter. These non-volcanic minerals and rock fragments were derived from the underlying Santa Fe Group. Some of the thicker beds of basaltic tephra are horizontally to sub-horizontally bedded and moderately well sorted, and contain one or more upward-fining sequences. Poorly to well developed reverse grading is present locally. Basaltic tephra is black (2.5Y 2/0), but some grains are altered and are tan (10YR hue). The phreatomagmatic deposits are more common in the lower part of this unit and composed of pale brown to very pale brown (10YR 6-7/3) clayey-silty or silty sand with 3-20% pebbles. The sediment is in medium to very thick beds and is internally massive, matrix-

supported, poorly sorted, and lacks sedimentary structures. Basaltic grains are subrounded and the granitic grains are subangular. The proportions of basalt to granite clasts vary greatly, but quartzite comprises less than 2% of the clasts. Minor, 5-10 cm thick, clast-supported lapilli lenses of very coarse-grained sand are locally found within this sediment. Up to five buried soils may be present on the phreatomagmatic deposits (Koning and Maldonado, 2001). The basaltic lapilli and phreatomagmatic deposits may locally be overlain by 1.5-6 m of light yellowish brown to very pale brown (10YR 6-7/4 and 10YR 8/2) silt-clay and very fine- to fine-grained sand with 2-5% basaltic and granitic pebbles and coarse sand. The top surface of this fine sediment is somewhat irregular because of post-depositional erosion. Overlying lava flows of unit QTcrv unconformably overlie this fine sediment and locally fill channels 10-15 m deep. The tephra has not been directly dated, but must immediately pre-date or overlap with ages of Cerros del Rio lava flows (2.2-2.7 Ma; Thompson et al., 2006). Thickness increases from 1-4 m near Las Campañas to as much as 60 m in maars near White Rock Canyon (mostly 10-30 m). *GRI Source Map ID 75593* (SIM 3179).

QTa - Ancha Formation (lower Pleistocene to upper Pliocene)

Tbta - Basaltic tephra and Ancha Formation, undivided (Pliocene)
Poorly exposed deposits of basaltic tephra about 15 cm to 5 m thick interstratified with sand, pebbly sand, and poorly sorted basaltic tephra-bearing sandstone of the Ancha Formation. Some of the basaltic tephra-bearing sandstone may have been deposited as hyperconcentrated flows. Mapped near the southeastern corner of the map area beneath the basaltic andesite of Arroyo Calabasas (Tbclf). Maximum exposed thickness is 20 m. *GRI Source Map ID 75593* (SIM 3179).

QTa - Ancha Formation (lower Pleistocene to upper Pliocene)
Fine- to coarse-grained alluvial slope deposits derived from the southwestern Sangre de Cristo Mountains, together with mostly coarse-grained ancestral Santa Fe River deposits. Alluvial slope deposits contain two distinct types of intercalated sediment: 1) moderately to well consolidated, silty-clayey sand (mostly very fine- to medium-grained sand with subordinate coarse- to very coarse-grained sand) containing minor, scattered pebbles; beds are medium to thick, tabular to broadly lenticular, and internally massive or bioturbated; and 2) weakly consolidated, coarse channel fills of gravelly sand, sandy gravel, and medium- to very coarse-grained sand; the channel fills are lenticular to broadly lenticular in form, commonly medium to thick, and generally 2-30 m in width. The proportion of coarse channel fills increases towards the Sangre de Cristo Mountains to the east and also towards the base of the deposit. Common colors of light yellowish brown (10YR 6/4), brownish yellow (10YR 6/6), very pale brown (10YR 7/3-4), and yellowish brown (10YR 5/4-6). Between approximately Interstate 25 and the modern Santa Fe River lies ancestral Santa Fe River deposits in the Ancha Formation; these consist of predominately sandy gravel interbedded with subordinate floodplain deposits of clayey-silty sand. In both alluvial slope and ancestral Santa Fe River deposits, the sand is arkosic and the gravel fraction contains greater than 20% granite clasts. There are minor interbeds of basaltic hydromagmatic deposits, which increase in abundance towards the Cerros del Rio volcanic field to the west. Unit generally overlies older Tesuque Formation with angular unconformity, but in the southern part of the Española basin it unconformably overlies Espinaso and Galisteo Formations. The Ancha Formation interfingers with basaltic lava flows of the Cerros del Rio volcanic field. Buried soils are locally preserved in the upper part of the unit. These soils have calcic (Btkb, Bkb, and Kb) horizons about 15–60 cm thick that display stage I to III carbonate morphology. Locally, these horizons are overlain by thin, eroded Btb horizons. Unit is 10-76 m-thick, locally as much as 90-100 m, with the greatest thicknesses being near the center of the Santa Fe embayment. The base of the Ancha Formation is lower than the straths associated with unit QTgt (Gravel terrace deposits, not in GRI data), so it post-dates that unit. It is partly contemporaneous with unit QTcrv (2.2-2.7 Ma; Thompson et al., 2006) because of interfingering relations. Near the top of the Ancha Formation are beds of Guaje pumice (Qbo) and Cerro Toledo Rhyolite pumice that were dated at 1.48-1.67 Ma using $^{40}Ar/^{39}Ar$ methods (Koning et al., 2002). A terrace fill deposit inferred to be inset into the Ancha Formation contains scattered pumice clasts that

were dated by $^{40}Ar/^{39}Ar$ methods, indicating an age of 1.2 Ma (Koning et al., 2002). Thus, most of the aggradation associated with the Ancha Formation occurred during 3-1.3 Ma. [Modifed from Koning and Hallett, 2000, Koning et al., 2002, and Read et al. 2004]. *GRI Source Map ID 75477* (OFR 531).

QTslg - Sierra Ladrones Formation (lower Pleistocene to upper Miocene)

Gravel deposited by axial river (ancestral Rio Grande). Restricted to outcrops in the southeastern corner of the quadrangle, but also found as clasts in Peralta Tuff at Tent Rocks, and in fault gouge along Pajarito fault on west side of Bland Canyon. Contains about 35-40% quartzite, 20% granitic and metamorphic rocks and the remainder mostly volcanic rocks. Clasts of Oligocene Pedernal Chert comprise 1 to 5% of most outcrops. In the adjacent Santo Domingo Pueblo SW quadrangle, axial gravel is interbedded with beds of Peralta Tuff Member of the Bearhead Rhyolite (Smith and Kuhle, 1997b) that yield $^{40}Ar/^{39}Ar$ ages of 6.81 ± 0.02, 6.81 ± 0.01, and 6.88 ± 0.01 Ma (W. McIntosh, personal communication, Feb. 1997). At Tent Rocks, rhyolitic hydromagmatic deposits dated at 6.90 ± 0.06 Ma (McIntosh and Quade, 1995; Smith, 2000), and clearly from a lower stratigraphic position than the samples providing the three ages above, contain accessory clasts derived from axial gravel deposits. Tephra, apparently reworked from the lower Bandelier Tuff, and dated at 1.62 ± 0.01 Ma (W. McIntosh, personal communication, Feb. 1997) is present approximately 20 m below the top of the Sierra Ladrones Formation in the Santa Fe River valley immediately upstream of Cochiti Dam in the Santo Domingo Pueblo quadrangle (Smith and Kuhle, 1997a). These dates limit the age of the Sierra Ladrones Formation outcrops in the Santo Domingo from late Miocene to early Pleistocene, although outcrops on this quadrangle are all of late Miocene age. *GRI Source Map ID 7218* (OF-GM 85).

QTc - Cochiti Formation (lower Pleistocene to Miocene)

QTc - Cochiti Formation (lower Pleistocene to Miocene)
Weakly lithified pebble to cobble gravel, massive to planar-bedded sand, thin (<0.3 m) beds of rhyolitic tephra and pumiceous alluvium, beds of fine sand and silt, and silt-rich debris flows containing volcanic clasts. Gravel fraction rich in andesitic and silicic rocks derived from west of the map area. The sand fraction is rich in lithic fragments and quartz. Includes older alluvium of Goff and others (1990) and Smith and others (1970). On both sides of the Rio Grande, between Sanchez Canyon and the Town of Cochiti Lake, upper 2–10 m of the Cochiti Formation consists of dark-colored sand containing beds and concentrations of pumice, some of it tubular and nearly aphyric, correlated with the ~1.8 Ma San Diego Canyon ignimbrite (Spell and others, 1990; Smith and Kuhle, 1998). Interbedded with unit Tsfa south of the Town of Cochiti Lake and near the intersection of Cochiti and Bland Canyons. Underlies lower Bandelier Tuff or piedmont alluvium. Dips gently northeast near the Town of Cochiti Lake, more steeply (>10°) near faults. Northwest of the Pajarito fault zone, Cochiti Formation of Goff and others (1990) is a black to gray volcaniclastic unit consisting of debris flows, local zones of fluvial sediments and andesitic cinder cone debris, and flows of andesite too thin to show at map scale, interbedded with volcanic rocks of the Keres Group (Gardner, 1985; Gardner and others, 1986; Smith and others, 2001). Thick deposits tend to be covered by colluvium, estimated maximum thickness >30 m, base not exposed. *GRI Source Map ID 7228* (SIM 3194).

QTc - Cochiti Formation (Upper Miocene to Lower Pleistocene)
Volcanic sand and gravel in poorly sorted, tabular beds. Clasts consist of Keres Group volcanic rocks with a distinct upward increase in the abundance of devitrified and altered rhyolite at the expense of vitric rhyolite. Gradationally overlies the upper Miocene Peralta Tuff Member of the Bearhead Rhyolite (Smith and Lavine, 1996; Smith, 2000). The basal contact at Tent Rocks is located about 10 m above a 6.79 ±0.05 Ma pyroclastic deposit (McIntosh and Quade, 1995). A 6.16 ± 0.07 Ma (W. McIntosh, personal communication, Oct. 1997) rhyolitic tephra is present in lower beds of the formation at Tent Rocks. East of Tent Rocks, the lower Pleistocene Bandelier Tuff (Qbo) is present within the uppermost Cochiti Formation. In the Cochiti Dam quadrangle, the upper Cochiti Formation contains primary and reworked

tephra-fall beds dated at 1.87 ± 0.01 Ma and 1.84 ± 0.02 Ma by $^{40}Ar/^{39}Ar$ (W. McIntosh, personal communication, Feb. 1997) and correlated, by visual comparison, to the San Diego Canyon A and B ignimbrites. The Cochiti Formation is interbedded with unit QTslg near the southeastern corner of the quadrangle. *GRI Source Map ID 7218* (OF-GM 85).

Tpv - Volcaniclastic deposits, Paliza Canyon Formation (Miocene)
Black to gray to pale pink volcaniclastic unit consisting predominately of lahars, block and ash flows, and other debris flows formed contemporaneous with Paliza Canyon Formation volcanism; locally contains hyperconcentrated flow and fluvial deposits, cinder deposits, and pyroclastic fall deposits; contains andesite to dacite flow breccias and andesite lava flows too small or thin to map; unit has accumulated in small basins and topographic lows between Paliza Canyon volcanoes; unit generally thickens to south, east, and north into developing basin of the Rio Grande rift; Tpv bracketed between 8.7 and about 11 Ma within the St. Peter's Dome area; intruded and overlain by the Bearhead Rhyolite; overlies Canovas Canyon Rhyolite tuff and Santa Fe Group; relations with the Puye Formation are not exposed but presumably Tpv underlies and interfingers with these units beneath the southwestern Pajarito Plateau; maximum exposed thickness about 450 m; unit mapped according to the definition of Smith and Lavine (1996). *GRI Source Map ID 7224* (OF-GM 42).

Tc - Tertiary Cochiti Formation, Santa Fe Group (upper Miocene to Pliocene)
Volcaniclastic sediments with pebble to cobble-sized clasts derived primarily from Paliza Canyon, Canovas Canyon, and Bearhead rhyolite units in the study area. This unit includes conglomeratic sandstones interbedded with fine-grained sands and silts, covering much of the southern and southeastern portion of the quadrangle. Maximum thickness is approximately 100 meters. *GRI Source Map ID 6630* (OF-GM 74).

QTsfa - Santa Fe Group, axial channel facies (lower Pleistocene and Pliocene)

Slightly lithified pebble to cobble gravel rich in rounded clasts, arkosic sand, and thin beds of silty sand. Coarse units are 0.5–3.0 m thick, massive to cross-bedded, and locally planar-bedded. Gravel generally >70 percent quartzite, granite and other resistant rocks from northern New Mexico; andesitic and dacitic rocks from the Jemez Mountains common locally; vesicular basalt uncommon. Matrix quartzose or arkosic. Along White Rock Canyon, locally includes areas of pink silty sandstone that may correlate with the middle Santa Fe Group. Maximum thickness along Cañada de Cochiti; extensive exposures near Medio Canyon and in the southern part of the quadrangle on both sides of the Rio Grande. Fills channels in and locally interbedded with Cochiti Formation (QTc). Lies beneath landslide deposits, Pliocene basalt, or hydromagmatic deposits at most exposures. Paleocurrent direction measured on channels, gravelly crossbeds, and imbricated cobbles range from 140°–230°, and averages about 180°. Mainly undeformed except near faults. Near the mouth of Medio Canyon interlayered with a basaltic flow dated at about 2.5 Ma (Bachman and Mehnert, 1978). Thickness 5 to >70 m. *GRI Source Map ID 7228* (SIM 3194).

QTpf - Puye Formation (lower Pleistocene to lower Pliocene)

QTp - Puye Formation (Pliocene)
Thin deposit of poorly exposed gravel above north wall of upper Quemazon Canyon; poorly exposed layer of gravel beneath Qbo in upper Frijoles Canyon; composed almost entirely of dacitic materials shed from the Tschicoma Formation; bracketed between about 2 and 5 Ma (Goff and Gardner 2004); maximum thickness about 15 m. *GRI Source Map ID 75592* (GM 79).

Tp - Puye Formation (Pliocene)
Light to dark gray fanglomerates derived from Tschicoma lavas (Griggs, 1964; Gardner et al., 1986; Waresback, 1986; Turbeville et al., 1989). Silt and sand layers interbedded with cobble to boulder-sized

conglomerates deposited as debris flows, lahars, and alluvial fans. Clasts are typically rounded to sub-rounded and include a wide variety of dacitic and rhyodacitic lavas. Rhyodacite of Rendija Canyon and dacite of Caballo Mountain clasts are common. Lower Puye Formation deposits that overlie Santa Fe Group sediments east of the study area include clasts of rhyodacite of Rendija Canyon , suggesting a major eastward progradation of Puye Formation following the eruption of the Rendija Canyon rhyodacite at ~ 5.0 Ma. Reneau and Dethier (1996) note that deposition of the Puye Formation was probably controlled by blockage of the Rio Grande by volcanism in the Cerros del Rio volcanic field located to the southeast of the quadrangle. Age range of exposed Puye Formation is ~ 2.4 to 5.3 Ma (WoldeGabriel et al., 2001). Maximum thickness is ~ 100 meters. Thin beds of tephras and/or ignimbrites (Tpi) are interbedded with these sediments. In the middle reaches of Guaje Canyon, on the south side of the canyon, <0.5 m layers of tephra and ignimbrite are interbedded; the entire deposit is 6 to 10 m thick. The contact relations in the middle portion of Guaje Canyon are obscure, but this deposit appears to lie between Rendija Canyon rhyodacite and Puye Formation. The tan ignimbrite contains abundant gray pumice fragments, quartz, sanidine, obsidian, and lithic fragments. A second set of exposures occurs on the south side of Guaje Canyon along the old road into the canyon. One tephra is exposed near the canyon bottom and one is near the top of the Puye Formation. The upper tephra gives a $^{40}Ar/^{39}Ar$ age of 4.01 ± 0.22 Ma. The tephras are clast-supported pumice fall < 1 m thick. Clasts range in size from 0.5-1.0 cm. Clots of large (1-3 mm), fresh, euhedral amphibole crystals are present throughout the sample. Some clots include small, uncommon felsic minerals that are impossible to identify using a binocular microscope. Other clots have rare occurrences of biotite, but, for the most part, these clots are monominerallic. Lithics include light gray clasts of glassy and stony lava. Clay is pervasive as an alteration product, but a gritty texture suggests that primary glass may still be present. Maximum thickness is ~ 6 meters. *GRI Source Map ID 6633* (OF-GM 55).

QTpf - Puye Formation fanglomerate (lower Pliocene to lower Pleistocene)
Weakly lithified stream-flow and debris-flow sediment derived from the erosion of Tchicoma Dacite domes in the Los Alamos area. Exposed west of the Rio Grande except for an isolated outcrop south of the mouth of Cañada Ancha. Fills channels cut in rocks of the undivided Santa Fe Group and in most locations is exposed beneath quartzite-rich cobble gravel (Totavi Lentil) or phreatomagmatic deposits. However, along Los Alamos Canyon this fanglomerate fills a channel incised into cobble gravel of the Totavi Lentil (Puye Formation). Stream-flow sediment consists of pebble to boulder gravel, massive to planar-bedded sand, thin (<1 m) beds of dacitic tephra and pumiceous alluvium, and beds of fine sand and silt. Gravel beds generally 0.5-3.0 m (1.5-10 ft) thick. Debris flows are boulder-rich and range from 0.3 m (1 ft) to about 5.0 m (16 ft) thick. Clast and matrix lithology mainly dacite derived from the Tschicoma Formation of the Jemez Mountains, but Precambrian material composes >30% of some fluvial units. Paleocurrent directions measured on channels, gravelly crossbeds, and imbricated cobbles range from about 90° to 200°and average about 150°, slightly south of the trend of present canyons. Faulted locally near the mouth of Ancho Canyon; otherwise undeformed. Pumiceous Puye gravel 8 km (5 mi) north-northwest of Otowi Bridge gave a fission-track age of 2.9 Ma (Table 1 of Dethier, 1997). Immediately north of the northwestern corner of the map, a pumice lapilli bed at the base of the Puye Formation returned an age of 5.31 ± 0.02 Ma (WoldeGrabriel et al., 2001). Turbeville et al. (1989) report that the upper part of the Puye Formation may be as young as 1.7 ± 0.1 Ma northwest of the White Rock quadrangle. Thus, the age of the Puye Formation fanglomerate is 5.3-1.7 Ma. Thickness of 5-30 m (16-100 ft) in the map area [Modified from Dethier, 1997]. *GRI Source Map ID 75477* (OFR 531).

Tp - Puye Formation (Pliocene)
Moderately lithified pebble to cobble gravel, boulderrich debris flows, massive to planar-bedded sand, thin (<2.0 m) beds of dacitic and rhyolitic tephra and pumiceous alluvium, lacustrine beds containing fine sand, silt, and clay, and local beds of basaltic scoria (Waresback, 1986). Gravel fraction rich in dacitic rocks derived from Tschicoma Formation sources west of the map area. Sand fraction generally rich in dacitic fragments and angular quartz grains. Paleocurrent directions (azimuth) range from 40° to 160°. At many locations, basal 10–20 m is rich in pumiceous alluvium and mudflows, and overlies one or more beds of axial-river gravel (Totavi Lentil of Griggs, 1964), each 3–8 m thick (too thin to show at this map

scale) that rest on silty sand of the Santa Fe Group. Axial gravels are about 15 m thick in lower Bayo and Guaje Canyons. In the adjacent White Rock quadrangle a 4.5-m-thick bed of axial-river gravel crops out in Los Alamos Canyon beneath 2.3 Ma basalt (Dethier, 1997) at about 6,165 ft elevation, about 80 m above the basal contact (Waresback, 1986). Paleocurrent directions in axial-river gravels range from 160° to 230° (azimuth) and average about 215°. Thickness more than 90 m, but reported as thick as 221 m in the subsurface southwest of the quadrangle (Griggs, 1964). Locally interbedded with fluvial deposits of Santa Fe Group (Chamita Formation) in eastern Guaje and Los Alamos Canyons and central Santa Clara Canyon; unconformably overlies bedded sediment of the Santa Fe Group (Chamita and Tesuque(?) Formations) elsewhere. Underlies lower part of Bandelier Tuff or piedmont alluvium that locally contains tephra of the about 1.8 Ma San Diego Canyon ignimbrite (Waresback and Turbeville, 1990). In eastern Los Alamos Canyon (adjoining White Rock quadrangle), Puye alluvial deposits and basaltic cinders are capped by a 2.57 Ma basalt (Dethier, 1997). In Guaje Canyon at 35° 54.75' N. lat, 106° 13.37' W. long, a hornblende separate from pumice in a tephra layer about 80 m below the local top of the formation gave a $^{40}Ar/^{39}Ar$ age of 4.76 ± 0.13 Ma (WoldeGabriel and others, 2001; sample DN–97–17b). Pumice from a correlative deposit in lower Rendija Canyon gave a whole-rock K-Ar age of 2.5 ± 0.1 Ma (Waresback and Turbeville, 1990). Slopes gently (0.5°–2°) eastward except in sections 16 and 17, T. 19 N., R. 7 E., where the Puye dips 12°–18° northwest to northeast in the vicinity of Miocene basalt outcrops. *GRI Source Map ID 6547* (MF 2419).

QTpt - Puye Formation, ancestral Rio Grande facies (lower Pleistocene to lower Pliocene)

QTpt - Puye Formation, ancestral Rio Grande facies (lower Pliocene to lower Pleistocene)
Slightly lithified pebble to cobble gravel (with abundant clasts of Proterozoic quartzite and granite), sand, and thin beds of silty sand deposited by the Rio Grande in the Pliocene. Unit is generally found west of the modern Rio Grande; east of the Rio Grande, unit is exposed at one outcrop south of the mouth of Cañada Ancha. Unit interfingers with the Puye Formation fanglomerate and underlies the fanglomerate in upper White Rock Canyon. The Puye Formation pre-dates overlying Cerros del Rio volcanic rocks (2.2-2.7 Ma; Thompson et al., 2006). This unit lies beneath landslide deposits, Pliocene alluvium, or phreatomagmatic deposits at most exposures. Coarse units are 0.5-3.0 m (1.5-10 ft) thick, cross-bedded, and locally planar bedded. Clasts are generally composed of >80% quartzite and other resistant lithologies from northern New Mexico, but granitic clasts from the southern Sangre de Cristo Range are common locally. Paleocurrent directions measured on channels, gravelly crossbeds, and imbricated cobbles range from 160° to 220° and average about 180°. Mainly undeformed. Unit pre-dates the overlying Cerros del Rio volcanic rocks (2.2-2.7 Ma; Thompson et al., 2006). The aforementioned stratigraphic relations indicate that preserved ancestral Rio Grande facies of the Puye Formation is 5.3-2.7 Ma. Thickness 5-45 m (16-150 ft). [modified from Dethier, 1997]. *GRI Source Map ID 75477* (OFR 531).

Tpt - Puye Formation, ancestral Rio Grande facies (Totavi Lentil) (Pliocene)
Pebble to cobble gravel rich in clasts of quartzite, intrusive igneous rocks and other Precambrian lithologies, and in highly altered volcanic lithologies from sources north and east of the Pajarito Plateau (Griggs, 1964; Dethier, 1997); may contain thin beds of sand and silty sand; inlcudes minor lacustrine deposits north of map area; interbedded with mafic hydromagmatic deposits (Tcbm) in lower Frijoles Canyon; these exposures bracketed by $^{40}Ar/^{39}Ar$ dates between 2.75 and 2.78 Ma (WoldeGabriel et al., 1996); maximum exposed thickness about 20 m; maximum thickness in drill hole intercepts at least 98 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpl - Puye Formation, lacustrine facies (late(?) Pliocene)

Lacustrine beds containing fine sand, silt, and clay, a decimeter thick bed of dacitic and basaltic tephra (Waresback, 1986), and overlying sandy piedmont alluvium and debris flows separated by buried soils.

Includes a bed of pebbly axial gravel 1–2.5 m thick on mesas near Santa Clara Canyon. Thickness 4–15 m; locally more than 25 m near lower Barrancas Canyon. Overlies silt-rich to coarse gravel deposits of the Puye Formation. Overlain by unit QTtp or Bandelier Tuff. Mapped where deposits are thickest or where they cap mesas from near Garcia and Barrancas Canyons to north of Santa Clara Canyon. These clays, locally as thick as 12 m, form the failure surface for landslide complexes in the south-central part of the map area. *GRI Source Map ID 6547* (MF 2419).

Tpi - Puye Formation, interbedded thin beds of tephras and/or ignimbrites (Pliocene)

Thin beds of tephras and/or ignimbrites (Tpi) are interbedded with these sediments. In the middle reaches of Guaje Canyon, on the south side of the canyon, <0.5 m layers of tephra and ignimbrite are interbedded; the entire deposit is 6 to 10 m thick. The contact relations in the middle portion of Guaje Canyon are obscure, but this deposit appears to lie between Rendija Canyon rhyodacite and Puye Formation. The tan ignimbrite contains abundant gray pumice fragments, quartz, sanidine, obsidian, and lithic fragments. A second set of exposures occurs on the south side of Guaje Canyon along the old road into the canyon. One tephra is exposed near the canyon bottom and one is near the top of the Puye Formation. The upper tephra gives a $^{40}Ar/^{39}Ar$ age of 4.01 ± 0.22 Ma. The tephras are clast-supported pumice fall < 1 m thick. Clasts range in size from 0.5-1.0 cm. Clots of large (1-3 mm), fresh, euhedral amphibole crystals are present throughout the sample. Some clots include small, uncommon felsic minerals that are impossible to identify using a binocular microscope. Other clots have rare occurrences of biotite, but, for the most part, these clots are monominerallic. Lithics include light gray clasts of glassy and stony lava. Clay is pervasive as an alteration product, but a gritty texture suggests that primary glass may still be present. Maximum thickness is ~ 6 meters. *GRI Source Map ID 6633* (OF-GM 55).

Tog - Old fluvial gravel (upper Pliocene (?))

Alluvial to fluvial gravel and sandstone deposits underlying the Otowi Member of the Bandelier Tuff. Clasts are generally sub-rounded to well rounded, and are pebble to boulder size. Clasts are in a silt to medium sand size matrix or are clast supported. Sand grains in matrix are angular and poorly sorted. Gravel is usually present at the base of the deposit and red-brown fine-grained sandstone is present at the top. These deposits could be equivalent to gravels of the Quaternary/Tertiary Cochiti Formation (Smith and Lavine, 1996), which contains predominantly rounded, volcanic clasts. Varies in thickness from ~1 – 12 m. *GRI Source Map ID 6630* (OF-GM 74).

Basalt of Hill 7033

Lava flows and associated near-vent deposits erupted from small, eroded cinder and spatter cones in southeast part of map area. Part of a chain of northeast-trending vents that coincides with mapped lineament inferred to be one of several north to northeast trending faults in the map area. Exposed thickness typically 2–25 m, thicker near vent areas.

Tbxc - cinder deposits (Tertiary)

Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *GRI Source Map ID 75593* (SIM 3179).

Tbx - lava flows (Tertiary)

Thin (<3 m), medium gray basalt lava flows (47–49 weight percent SiO_2) exposed in upper reaches of Arroyo Calabasas, on the adjacent Turquoise Hill quadrangle, in the southeast part of the map area. Flows are laterally discontinuous with massive interiors and vesiculated flow tops, largely covered with sheet wash alluvium. Olivine phenocrysts (1–2 mm) are common in a fine-grained microcrystalline groundmass. An $^{40}Ar/^{39}Ar$ isotopic age of 2.03±0.35 Ma was obtained from a lava flow south of the map area on the adjacent Tetilla Peak quadrangle (Sawyer and others, 2002). Reversed paleomagnetic and aeromagnetic signature. *GRI Source Map ID 75593* (SIM 3179).

Andesite of Ortiz Mountain

Massive andesite lava flows composed of a lower aerially extensive, basal crystal-rich lava flow and discontinuous near-vent deposits on the upper flanks of Ortiz Mountain. Ortiz Mountain is the southernmost of a series of andesite eruptive centers of largely unknown compositional range outside of the map area in the adjacent White Rock Canyon quadrangle (Dethier, 1997).

Toc - cinder deposits (Tertiary)

Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *GRI Source Map ID 75593* (SIM 3179).

To - lava flows (Tertiary)

Medium-gray to black-glassy, blocky andesite lava flows (59–63 weight percent SiO_2) containing abundant phenocrysts of plagioclase and pyroxene, and locally minor olivine, hornblende and opaque minerals. An $^{40}Ar/^{39}Ar$ isotopic age of 2.32±0.06 Ma (sample 96TMP14) was obtained from near the southeastern extent of the basal lava flow. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 225 m. *GRI Source Map ID 75593* (SIM 3179).

Basaltic andesite of Twin Hills

Comprises three adjacent, dissected vent areas and associated lava flows in the Twin Hills and Cerro Rito areas. Flank-lava flows from the Twin Hills vent complex and the unnamed eruptive center 1 km to the south largely flowed northeast. Exposures of paleovalley-filling lavas erupted along Thirty-One Draw may include petrologically similar flows from both the Twin Hills and Cerro Rito eruptive centers. The Twin Hills and unnamed centers to the south are cut by northeast trending dikes. The Cerro Rito center is characterized by a prominent breached summit crater cut by discontinuous northwest trending dikes.

Ttoc - cinder deposits (Tertiary)

Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, locally interbedded with medium gray to red oxidized lava flows. *GRI Source Map ID 75593* (SIM 3179).

Tto - lava flows (Tertiary)

Thin (<3 m) medium-gray lava flows (50–53 weight percent SiO_2) forming cliff exposures along Thirty-One Draw. Lava flows thin to the north and were likely sourced near the current head of Thirty-One Draw and were restricted to deposition in a shallow paleovalley bordered on the east by Thirty-One Draw. Flows contain olivine and clinopyroxene phenocrysts (2–3 mm) and sparse glomerocrysts of olivine +

pyroxene. Thin platy fracturing is common, particularly near the base of lava flows. An $^{40}Ar/^{39}Ar$ isotopic age of 2.53±0.04 Ma (sample 2TMP01) was obtained from a northeast-trending dike on the western flank of Twin Hills. Maximum exposed thickness in the Thirty-One Draw area is 20 m. Near vent deposits are medium-gray to red oxidized vesicular lava flows and blocky erosional flow remnants intercalated with spatter agglutinate and scoria in the Twin Hills and Cerro Rito areas. Flows contains ubiquitous olivine phenocrysts (< 1 mm) and resorbed plagioclase and quartz xenocrysts (1.3 mm) in a fine-grained holocrystalline groundmass. Reversed aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 175 m. *GRI Source Map ID 75593* (SIM 3179).

Basalt of Hill 7065

Eroded and dissected near vent deposits and flank lava flows preserved on the northwest and southeast facing flanks of extensive lavas flows erupted from a small center marked by near vent pyroclastic deposits of an eroded cinder cone on the southeast side of Cerro Micho. These lava flows filled a west- to northwest-trending paleotopographic valley currently occupied by Arroyo Eighteen. Lavas erupted from two source areas on the northwest flank of Cerro Micho and filled a small north-trending paleovalley cut into deposits of Tcmc.

Ttdc - cinder deposits (Tertiary)

Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, locally interbedded with medium gray to red oxidized lava flows. *GRI Source Map ID 75593* (SIM 3179).

Ttd - lava flows (Tertiary)

Medium to dark gray basaltic foliated lava flows (50–52 weight percent SiO2), typically 2–5 meters thick with aa bases and vesicular tops. Most flows are sparsely phyric containing small (less than 1 mm) olivine and pyroxene phenocrysts in a fine-grained intersertal to glassy groundmass. Flows thickened locally where ponded against paleotopographic barriers and thin proximal to vent areas. An $^{40}Ar/^{39}Ar$ isotopic age of 2.55±0.04 Ma (sample 5MRG-4) was obtained from a lava flow on the northwest flank of Cerro Micho. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 30–35 m in Arroyo Eighteen and thicker (up to 100 m) where comprised primarily of eroded near vent deposits northwest of Cerro Micho. *GRI Source Map ID 75593* (SIM 3179).

Basalt of Tetilla Hole

Massive, medium-gray, basaltic (50 weight percent SiO_2) lava flows that underlie the upper reaches of Arroyo Tetilla. Flows are thick, up to 17 m, with aa bases, vesicular tops with elongate vesicles, and minor interbedded bombs and scoria. Flow direction is to the north and flows grade laterally to the south into preserved remnants of vent area composed of cinder, scoria, bombs and agglutinate. Olivine phenocrysts and small pyroxene clots are common, groundmass is dense and fine grained. An $^{40}Ar/^{39}Ar$ isotopic age of 2.49±0.05 Ma (sample 96TMP22a) was obtained from the uppermost lava flow at Tetilla Hole. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 80 m.

Tbtc - cinder deposits (Tertiary)

Dissected cinder cones composed of near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *GRI Source Map ID 75593* (SIM 3179).

Tbt - lava flows (Tertiary)

Massive, medium-gray, basaltic (50 weight percent SiO_2) lava flows that underlie the upper reaches of Arroyo Tetilla. Flows are thick, up to 17 m, with aa bases, vesicular tops with elongate vesicles, and minor interbedded bombs and scoria. Flow direction is to the north and flows grade laterally to the south into preserved remnants of vent area composed of cinder, scoria, bombs and agglutinate. Olivine phenocrysts and small pyroxene clots are common, groundmass is dense and fine grained. An $^{40}Ar/^{39}Ar$ isotopic age of 2.49±0.05 Ma (sample 96TMP22a) was obtained from the uppermost lava flow at Tetilla Hole. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 80 m. *GRI Source Map ID 75593* (SIM 3179).

Basalt of Colorado Peak

Includes erosional remnants of two volcanic centers built on the northwest and southeast flanks of Colorado Peak. Deposits include near vent pyroclastic deposits and associated flank lava flows. Erupted lavas flowed away from the paleotopographic high underlain by Tca/Tcac toward the current drainages occupied by Arroyo Tetilla to the south and Arroyo Eighteen to the north. An $^{40}Ar/^{39}Ar$ isotopic age of 2.53±0.01 Ma (sample 2MRG–5) was obtained from a lava flow near the base of the section in Arroyo Colorado. Reverse polarity based on paleomagnetic determination and aeromagnetic signature.

Tcpcd - cinder deposits (Tertiary)

Dissected cinder cones comprised of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *Note: Symbol in source data is Tcbc. GRI Source Map ID 75593* (SIM 3179).

Tcb - lava flows (Tertiary)

Medium- to dark-gray, massive, basaltic (49–50 weight percent SiO_2) lava flows (3–5 m thick).

Phenocrysts of olivine, typically small, less than 1 mm diameter but occur up to 4 mm in diameter, and clinopyroxene with common olivine+clinopyroxene clots up to several millimeters in a fine grained holocrystalline groundmass. Xenocrysts of resorbed quartz and plagioclase up to several millimeters in diameter are common. Maximum exposed thickness is 120 meters although the section may reflect apparent thickening due to offset along north-trending normal faults. *GRI Source Map ID 75593* (SIM 3179).

Basalt of Cañada Ancha

Medium- to dark-gray lava flows exposed along the northeastern margin of the map area and along Cañada Ancha in the adjacent Agua Fria quadrangle (Shroba and others, 2006). Comprises three informal map units produced by discrete eruptive events from unknown source vents presumed to underlie younger deposits of the map area. Only the upper units (Tbu and Tbuc) are exposed in the map area but the nomenclature is retained for consistency with unit designation in the adjacent Agua Fria quadrangle. The basalt of Cañada Ancha is overlain by the andesite of Ortiz Mountain at the northern exposed extent.

Tbuc - cinder deposits (Tertiary)

Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. Locally includes thin, isolated deposit of cinder, not necessarily reflecting near vent proximity. This deposit may reflect lava flow rafting of near-vent pyroclastic deposits

away from vent areas now presumed buried beneath Qtoc in the Twin Hills area. *GRI Source Map ID 75593* (SIM 3179).

Tbu - lava flows (Tertiary)

Basalt to basaltic andesite lava flows that cap an eastward-sloping surface on the west side of Cañada Ancha. Lava flows contain moderately abundant, equant olivine phenocrysts, sparse clinopyroxene phenocrysts, and ubiquitous resorbed plagioclase xenocrysts. Lava flows are lobate and discontinuous, and vary in thickness from 1.5 to 5 m. Flows have reversed magnetic polarity based on paleomagnetic signature and overlie 2.3–2.4 Ma lava flows of unit Tbm in the Agua Fria quadrangle (Shroba and others, 2006). Maximum exposed thickness is 8 m. *GRI Source Map ID 75593* (SIM 3179).

Basalt of Hill 6929

Lava flows and near vent pyroclastic deposits from two centers, preserved in the northcentral part of the map area. Locally, near-vent deposits unassociated with any lava flows, are preserved on the southeast flank of Montoso Peak. Additional deposits occur west of Ortiz Mountain where a prominent northeast-trending dike cuts eroded cinder deposits. Lava flows abut deposits of Ttx, Qto and Tm to the southeast, south and west respectively. Reverse magnetic polarity based on fluxgate magnetometer determination.

Tbzc - cinder deposits (Tertiary)

Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *GRI Source Map ID 75593* (SIM 3179).

Tbz - lava flows (Tertiary)

Medium- to dark-gray, basaltic to basaltic andesite lava flows, proximal to associated cinder deposits are thin (2–3 m) and discontinuous. Some lava flows along the eastern and western flanks of Montoso Peak are likely derived from vent areas to the north of the map area on the White Rock quadrangle. Phenocrysts of olivine, ubiquitously altered to iddingsite, and lesser amounts of pyroxene are typical. Quartz and plagioclase xenocrysts are present locally. Maximum exposed thickness is 30 m, base not exposed. *GRI Source Map ID 75593* (SIM 3179).

Basaltic andesite of Arroyo Eighteen

Lava flows and associated near-vent pyroclastic deposits erupted from small cinder cones at the head of Arroyo Eighteen. Erupted lavas flowed westward along a paleodrainage coincident with Arroyo Eighteen. An $^{40}Ar/^{39}Ar$ isotopic age of 2.56±0.02 Ma (sample 3MRG–6) was obtained from a lava flow in a tributary to Arroyo Montoso near the western edge of the map area. Reverse polarity based on paleomagnetic determination and aeromagnetic signature.

Taec - cinder deposits (Tertiary)

Dissected cinder cones comprised of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. *Note: Symbol in source data is Qaec. GRI Source Map ID 75593* (SIM 3179).

Tae - lava flows (Tertiary)

Qae - Basaltic andesite of Arroyo Eighteen (Tertiary)
Medium-gray, massive basaltic andesite (55–57 weight percent SiO_2) lava flows (3–5m thick) containing sparse olivine ± pyroxene phenocrysts and abundant xenocrysts of plagioclase and quartz. Lava flows erupted from small cinder cones at the head of Arroyo Eighteen on the adjacent Montoso Peak quadrangle to the east. Erupted lavas flowed westward along a paleodrainage coincident with Arroyo Eighteen. An $^{40}Ar/^{39}Ar$ isotopic age of 2.56±0.02 Ma (sample 3MRG6) was obtained from a lava flow in a tributary to Arroyo Montoso near the eastern edge of the map area. Reverse polarity based on paleomagnetic determination and aeromagnetic signature. Maximum exposed thickness is 65 m but is locally thickened or repeated by down-to-west normal faults. *GRI Source Map ID 7228* (SIM 3194).

Tae- Basaltic andesite of Arroyo Eighteen (Tertiary)
Lava flows and associated near-vent pyroclastic deposits erupted from small cinder cones at the head of Arroyo Eighteen. Erupted lavas flowed westward along a paleodrainage coincident with Arroyo Eighteen. An $^{40}Ar/^{39}Ar$ isotopic age of 2.56±0.02 Ma (sample 3MRG–6) was obtained from a lava flow in a tributary to Arroyo Montoso near the western edge of the map area. Reverse polarity based on paleomagnetic determination and aeromagnetic signature. *GRI Source Map ID 75593* (SIM 3179).

Tclf - Mafic lava flows (Pliocene)

Undivided unit of flows, dikes and associated cinder deposits of basalt, hawaiite, and mugearite from Cerros del Rio volcanic field best exposed east of the Rio Grande (Dunker et al., 1991); units generally contain phenocrysts of olivine, plagioclase ± clinopyroxene in a variety of groundmass types, depending on chemistry of magma and eruption style; may contain abundant xenocrysts of quartz, microcline, and Precambrian rock fragments (Iddings, 1890) from sedimentary rocks beneath the Pajarito Plateau; flows massive to sheeted, generally showing broad columnar joints; $^{40}Ar/^{39}Ar$ ages of most Cerros del Rio volcanic rocks range from 2.3 to 2.8 Ma (WoldeGabriel et al., 1996); $^{40}Ar/^{39}Ar$ age of hawaiite cone and flow at LANL Tech Area 33 (TA-33) 2.39±0.08 Ma; maximum exposed thickness about 40 m. *Note: Symbol in source data is Tcb. GRI Source Map ID 7224* (OF-GM 42).

Tcba - Benmorite (Pliocene)

Thick lava flow exposed in upper walls of lower Frijoles Canyon and adjacent White Rock Canyon; contains phenocrysts of olivine, clinopyroxene, hypersthene and plagioclase in a trachytic groundmass; contains rare xenocrysts of quartz with clinopyroxene reaction rims; contains rare plagioclase-pyroxene clots; locally contorted and flowbanded within upper two thirds of flow; erodes into relatively thin plates; lower part of flow generally massive and cut by widely spaced columnar joints; overlain by Tshirege Member, Bandelier Tuff; overlies mafic lava flows and hydromagmatic deposits (Tcbc and Tcbm); $^{40}Ar/^{39}$ Ar age 2.75±0.08 Ma (WoldeGabriel et al., 1996); maximum exposed thickness about 70 m. *GRI Source Map ID 7224* (OF-GM 42).

Tcbc - Cinder deposit (Pliocene)

Basalt scoria, bombs, and associated thin lavas from partially exposed cone in east wall of Frijoles Canyon just upstream of Upper Falls; contains phenocrysts of olivine and plagioclase in glassy, vesicular groundmass; overlain by thin (0.5 m) sequence of hydromagmatic deposits and surrounded by intracanyon deposit of the Tshirege Member, Bandelier Tuff; relations with other Cerros del Rio volcanic rocks uncertain; maximum exposed thickness about 25 m. *GRI Source Map ID 7224* (OF-GM 42).

Tcbm - Mafic hydromagmatic deposits (Pliocene)

Layered hydromagmatic (maar) deposits consisting of cinders, ash, and decomposed glass with pebble- to boulder-sized fragments of quartz, microcline, volcanic rocks, quartzite, intrusive igneous rocks and other lithologies from sedimentary rocks beneath the Pajarito Plateau; magmatic component is primarily basalt; contains numerous interbedded, mafic lava flows (Tcbc) too thin or discontinuous to map; contains beds and lenses of ancestral Rio Grande gravels (QTpt); Tcbm most common near the axis of the ancestral and present Rio Grande (Heiken et al., 1996); formed by interaction of mafic magmas with shallow groundwaters or surface water (Fisher and Schminke, 1984); deposits show combinations of planer beds, cross beds, and surge beds; some beds contain accretionary lapilli; glass commonly alters to yellow-brown clay (palagonite); incorrectly correlated with the Chaquehui Formation by Purtymun (1995); overlies and interbedded with Puye Formation; overlies Santa Fe Group (Tsfu, described below) in exposures along Rio Grande upstream of Frijoles Canyon;$^{40}Ar/^{39}Ar$ age of basalt lava near base of maar sequence in mouth of Chaquehui Canyon just east of map area is 2.78±0.04 Ma (WoldeGabriel et al., 1996); maximum exposed thickness about 150 m. *GRI Source Map ID 7224* (OF-GM 42).

Tglp - Gravel of Lookout Park (Pliocene to Miocene)

Tglp - Gravel of Lookout Park (Upper Pliocene)
Cobble to boulder gravel resting on a broad pediment surface cut primarily on Cochiti Formation in the southwestern part of the quadrangle. The gravel is composed mostly of Keres Group andesite and rhyolite clasts, and is 5-15 m thick. Gravel is inset below basalt of Santa Ana Mesa dated at 2.41 ±0.03 Ma, on the Santo Domingo Pueblo Southwest quadrangle (Smith and Kuhle, 1997b), and underlies lower Bandelier Tuff (1.61 Ma), indicating deposition during a short period of the late Pliocene. Remnants of a stage IV calcic soil horizon are present at the surface in some places. This older soil was stripped and then the gravel was largely buried in eolian sand and silt (Qpa) in which a new soil has formed with a stage II-stage III calcic horizon evident in various places. *GRI Source Map ID 7218* (OF-GM 85).

Tglp - Gravel of Lookout Park (Pliocene)
Stratified cobble to boulder gravel almost entirely derived from upper Miocene volcanic strata. Relative proportions of basalt, basaltic andesite, andesite, dacite and rhyolite clasts vary with the bedrock lithology of the local provenance. The Gravel of Lookout Park, as mapped in the Loma Creston quadrangle to the south of the map area, is both slightly older than and slightly younger than the upper Pliocene basalts (ca. 2.5 Ma) that cap Santa Ana Mesa (Chamberlin et al., 1999). *GRI Source Map ID 6630* (OF-GM 74).

Ttqc - Tschicoma Formation, upper Quemazon Canyon dacite (Pliocene)

Flow-banded to massive, slightly porphyritic lava with sparse phenocrysts of large plagioclase and small resorbed quartz in a trachytic groundmass of plagioclase, orthopyroxene, clinopyroxene, biotite, and opaque oxides; $^{40}Ar/^{39}Ar$ age is 2.92 ± 0.05 Ma (Kelley et al., in press); maximum exposed thickness is roughly 65 m. *GRI Source Map ID 75592* (GM 79).

Ttcb - Tschicoma Formation, Caballo Mountain dacite (Pliocene)

Ttcb - Caballo Mountain dacite (Pliocene)
Dome and flow complex of massive to sheeted, porphyritic lava containing phenocrysts of plagioclase, oxidized hornblende, clinopyroxene, rare rounded quartz, opaque oxides, and oxidized biotite; 40Ar/39Ar age is 3.06 ± 0.15 Ma (Broxton et al. 2007); maximum exposed thickness is about 200 m. *GRI Source Map ID 75592* (GM 79).

Ttcm - Dacite of Caballo Mountain (Pliocene)

Lavender to dark gray flowbanded
dacitic lavas and associated block and ash flows erupted from the vicinity of Caballo Mountain. Streaky, flow-banded lavender to red facies common. Lavas contain 10 –20% phenocrysts of plagioclase and hornblende with subordinate pyroxene, biotiteand quartz. At least three separate flows occur, the youngest containing more abundant hornblende. These flows extended in two main directions: one extending SSE of Caballo Mountain, capping the north canyon wall of Guaje Canyon, and one that flowed to the ENE of Caballo Mountain, extending to just west of Pine Springs. Sample from top of Caballo Mountain has age date of 3.03 ± 0.15 Ma (Broxton et al., 2007). *GRI Source Map ID 6633* (OF-GM 55).

Ttpm - Tschicoma Formation, Pajarito Mountain dacite (Pliocene)

Ttpm - Pajarito Mountain dacite (Pliocene)
Dome and flow complex of massive to sheeted, porphyritic lava containing phenocrysts of plagioclase, hypersthene, clinopyroxene, and opaque oxides in a devitrified groundmass; $^{40}Ar/^{39}Ar$ ages on geographically separated samples range from 2.93 to 3.09 Ma (Broxton et al. 2007); maximum exposed thickness is about 365 m. *GRI Source Map ID 75592* (GM 79).

Ttpm - Dacite of Pajarito Mountain, Tshicoma Formation (Pliocene)
Light to medium gray to reddish dacite lavas and associated block and ash flows erupted from Pajarito Mountain. Phenocrysts make up 10 – 24 % of the rock and consist of plagioclase (disequilibrium textures), clinopyroxene, orthopyroxene, and trace hornblende, Fe-Ti oxides, and apatite. Contains crystal clots of clinopyroxene and orthopyroxene. At least 2 major flows are observed in Los Alamos Canyon, overlying Rendija lavas. Brecciated basal horizons typical. Age dates range from 2.91 ± 0.06 to 3.07 ± 0.07 on Pajarito Mountain (WoldeGabriel, pers. communication) with a maximum thickness of ~ 180 meters in map area. *GRI Source Map ID 6633* (OF-GM 55).

Ttpm - Dacite of Pajarito Mountain, Tschicoma Formation (Pliocene)
Dome and flow complex of blue gray to pale pink, massive to sheeted, porphyritic dacite containing phenocrysts of plagioclase, hypersthene, clinopyroxene, and opaque oxides in a devitrified groundmass; contains clots of complexly zoned plagioclase and occasional clots of two pyroxenes; thick flows contain intervals of flow breccia; probably consists of several eruptive events; source is Pajarito Mountain west of map area; overlies hornblende dacite of Cerro Grande (Ttcg); locally underlies Tshirege Member, Bandelier Tuff; $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 3.4 to 2.9 Ma (WoldeGabriel, 2001, unpub.); maximum exposed thickness about 220 m. *GRI Source Map ID 7224* (OF-GM 42).

Ttcg - Tschicoma Formation, Cerro Grande dacite (Pliocene)

Tphd - Hornblende dacite of Cerro Grande (Pliocene)
Dome and flow complex of light to dark gray to pale pink, massive to sheeted porphyritic dacite containing phenocrysts of plagioclase, hypersthene, and conspicuous hornblende; the later two phases commonly show oxidized rims; contains microphenocrysts of plagioclase, hypersthene and clinopyroxene, and clots of hornblende, hypersthene, plagioclase, and opaque minerals; thick flows contain intervals of flow breccia; source is Cerro Grande west of map area; probably consists of several eruptive events; underlies Tpd and Tshirege Member, Bandelier Tuff; dates on widely separated samples range from 3.8 to 3.1 Ma (Dalrymple et al., 1967; WoldeGabriel, 2001, unpub.); $^{40}Ar/^{39}Ar$; maximum exposed thickness about 200 m. *GRI Source Map ID 7224* (OF-GM 42).

Ttcg - Cerro Grande dacite (Source Age)
Extensive dome and flow complex of massive to sheeted, porphyritic lava containing phenocrysts of plagioclase, hypersthene, and (typically) conspicuous hornblende; the latter two phases commonly show oxidized rims that may be difficult to see in hand sample; ages on widely separated samples

range from 2.88 to 3.35 Ma (Broxton et al. 2007); maximum exposed thickness is about 750 m. *GRI Source Map ID 75592* (GM 79).

Ttsd - Tschicoma Formation, Sawyer Dome dacite (Pliocene)

Dome and flow complex of massive, porphyritic lava containing phenocrysts of plagioclase, hypersthene, opaque oxides, and conspicuous hornblende; contains local mafic clots of plagioclase-hornblende as large as 10 cm in diameter; $^{40}Ar/^{39}Ar$ age of summit is 3.44 ± 0.30 Ma (Kelley et al., in press); maximum exposed thickness is 245 m. *GRI Source Map ID 75592* (GM 79).

Ttcr - Tschicoma Formation, Cerro Rubio dacite (Pliocene)

Massive to sheeted, fine-grained intrusive lava with phenocrysts of plagioclase, hornblende, orthopyroxene, biotite, and rare quartz; resembles Ttcd (described below); K-Ar age is 3.56 ± 0.36 Ma (Stix et al. 1988); maximum exposed thickness is 440 m. *GRI Source Map ID 75592* (GM 79).

Ttcd - Tschicoma Formation, dacite intrusion north of Cerro Rubio (Pliocene)

Massive to sheeted, fine-grained lava with small phenocrysts of plagioclase, hornblende, orthopyroxene, sparse biotite, and rare quartz; some columnar jointing visible around margins and top; $^{40}Ar/^{39}Ar$ age is 4.21 ± 0.12 Ma (Kelley et al., in press); maximum exposed thickness is 365 m. *GRI Source Map ID 75592* (GM 79).

Ttsc - Tschicoma Formation, Santa Clara Canyon dacite (Pliocene)

Faulted, plug-like body of massive to sheeted, porphyritic lava containing phenocrysts of plagioclase, sanidine, hornblende, biotite, and sparse quartz; resembles dacite on and near Cerro Rubio; unit not dated; maximum exposed thickness is 160 m. *GRI Source Map ID 75592* (GM 79).

Ttpd - Tschicoma Formation, Tschicoma Peak area dacite and rhyodacite, undivided (Pliocene)

Ttpd - Tschicoma Peak area dacite and rhyodacite, undivided (Pliocene)
Massive to sheeted, coarse porphyritic lavas having abundant phenocrysts of plagioclase and variable phenocrysts of biotite, hornblende, and rare clinopyroxene; younger lavas may contain phenocrysts of sanidine and quartz and 2-25-cm, elliptically shaped inclusions of mafic composition; $^{40}Ar/^{39}Ar$ ages are 3.57-4.46 Ma (Kempter et al. 2007); maximum exposed thickness >500 m. *GRI Source Map ID 75592* (GM 79).

Ttu - Tshicoma Formation Lavas, Undifferentiated (Pliocene)
This unit, which primarily consists of exposures on the Santa Clara Indian Reservation, represents unmapped territory since access to this region was not allowed. An unnamed center north of Santa Clara Canyon
(Smith et al., 1970) is the likely source for 3.79 ±0.17 to 4.39±0.13 Ma dacite (WoldeGabriel et al., 2006) exposed in Santa Clara Canyon just north of the quadrangle boundary. Although the majority of the rocks exposed in the canyon are believed to be Tschicoma Formation, older and younger rocks may exist. *GRI Source Map ID 6633* (OF-GM 55).

Ttrc - Tschicoma Formation, Rendija Canyon rhyodacite (Pliocene)

Ttrc - Rendija Canyon rhyodacite (Pliocene)
Dome and flow complex of massive to sheeted, highly porphyritic lavas with phenocrysts of quartz, sanidine, plagioclase, hornblende, and biotite; $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 3.50 to 5.36 Ma (Broxton et al. 2007; Kelley et al., in press); maximum exposed thickness approximately 500 m. *GRI Source Map ID 75592* (GM 79).

Ttrc - rhyodacite of Rendija Canyon, Tshicoma Formation (Pliocene)
Light to dark gray to red rhyodacitic lavas that form the central part of Sierra de Los Valles. Phenocrysts make up 11-16% of the rock and consist of plagioclase (megacrysts up to 2 cm across), alkali feldspar (both as sanidine and anorthoclase), and quartz (resorbed); subordinate biotite, clinopyroxene, and hornblende; and trace sphene, zircon, and Fe-Ti oxides. Massive, high-aspect ratio flows with associated block and ash flows where oversteepened lava flanks collapsed during flowage. Lavas outcrops can be massive and/or sheeted, and typically exhibit a knobby surface texture that spalls off 1-2 cm-size fragments (enhanced since the Cerro Grande fire). Rendija Canyon lavas north of Guaje Canyon contain moderate amounts of biotite. Maximum thickness is > 350 meters. Age dates range from 4.95 ± 0.06 to 5.03 ± 0.02 (Broxton et al., 2007). *GRI Source Map ID 6633* (OF-GM 55).

Ttrb - Tschicoma Formation, breccia, white to gray ignimbrite and tephra (Pliocene)

Exposed in a landslide scar in upper Guaje Canyon, west of Guaje Reservoir. Appears to overlie Tti (below). Lower portion includes large lithic fragments of sub-rounded boulders of Rendija Canyon lavas (Ttrc). Thin ash and surge beds (< 0.5 meters) occur in the sequence. The upper portion of thedeposit appears more as a brecciated lava, containing phenocrysts of plagioclase (some megacrysts), quartz, and lesser biotite and pyroxene. Age most likely comparable to the Rendija Canyon lavas with a maximum exposed thickness of ~ 60 meters. *GRI Source Map ID 6633* (OF-GM 55).

Tti - Tschicoma Formation, small-volume ignimbrites in upper Guaje Canyon, west of the reservoir (Pliocene)

In ascending order, these tuffs consists of 0.75 m of brown to gray ignimbrite, 13 cm of bedded tuffs, 0.64 m of white ignimbrite, and 0.98 m of light gray to lavender tuff breccia. Phenocrysts of plagioclase and trace amounts of quartz and biotite. Maximum exposed thickness is ~ 2.5 meters. Lower ignimbrite has age date of 5.32 ± 0.02 Ma (WoldeGabriel, pers. communication). *GRI Source Map ID 6633* (OF-GM 55).

Tbh - Bearhead Rhyolite (Pliocene to Miocene)

Tbh - Rhyolite intrusive rocks (Bearhead Rhyolite) (Pliocene to Miocene)
White to gray dikes, plugs, sills, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing sparse phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units are generally flow-banded; width of individual dikes shown on map are commonly exaggerated and may consist of many smaller sub-parallel dikes; associated lithic-rich tuffs (Tkpt) occur only in southwest part of map in Aspen Peak area; pervasive, hydrothermally altered plugs and dikes occur throughout west and southwest map area probably emanating from shallow underlying pluton; intrudes or overlies other Paliza Canyon Formation rocks; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); $^{40}Ar/^{39}Ar$ date on intrusion north of Aspen

Peak is 6.76 ± 0.10 Ma; date on Cougar Hill plug is 6.80 ± 0.05; date on Rabbit Hill dome is 6.65 ± 0.03 (Justet, 1996); maximum observed thickness about 170 m. *GRI Source Map ID 7225* (OF-GM 112).

Tbh - Bearhead Rhyolite (Pliocene to Miocene)
Dikes, plugs, and flows of aphyric to slightly porphyritic, devitrified to completely silicified rhyolite containing sparse phenocrysts of quartz, sanidine, plagioclase, biotite, opaque oxides ± hornblende; locally shows pervasive hydrothermal alteration consisting of quartz, chalcedony and/or opal, illite, Fe- and Mn-oxides, pyrite, and possibly other sulfides, alunite, jarosite, and gypsum; $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 4.81 to 783 Ma (Justet and Spell 2001; Kempter et al. 2007; Kelley et al., in press) maximum observed thickness about 100 m. *GRI Source Map ID 75592* (GM 79).

Tbr - Bearhead Rhyolite (Pliocene to Miocene)
White to gray intrusions, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing rare phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units are generally flow-banded; associated lithic-rich tuffs (Tkpt) occur only in extreme southeast part of map; small, hydrothermally altered plugs and dikes occur along fault zones in southeast map area; intrudes or overlies all other Keres Group rocks; apparently surrounded by Tpv in south-central map area; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); $^{40}Ar/^{39}Ar$ date on unnamed dome in uppermost San Juan Canyon is 6.38 ± 0.09 Ma (Justet, 1996); maximum observed thickness about 170 m. Two $^{40}Ar/^{39}Ar$ dates on the faulted rhyolite south of Cerro Pelado range from 7.6 to 7.8 Ma (W. McIntosh and L. Peters, NMBGMR). *GRI Source Map ID 7226* (OF-GM 111).

Tbr - Bearhead Rhyolite (Upper Miocene)
Lava domes and flows of white to pale pink to light gray rhyolite and volcanic breccias. Contains 1-3% phenocrysts of quartz, sanidine, biotite, ±minor plagioclase. Commonly strongly flow banded with vitrophyre near margins. Domes distributed along N-S and NE-SW striking faults. Erupted between 6.52-7.06 Ma (Justet, 1999). Maximum thickness is ~370 meters observed near the type locality of Bearhead Peak. *GRI Source Map ID 7218* (OF-GM 85).

Tbh - Bearhead Rhyolite (Miocene)
White to gray intrusions, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing rare phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units generally flow banded; intrudes or overlies all other Keres Group rocks; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); $^{40}Ar/^{39}Ar$ date on Rabbit Hill dome on west edge of map 6.65±0.03 Ma (Justet, 1996); maximum observed thickness about 60 m. *GRI Source Map ID 7224* (OF-GM 42).

Tbr - Bearhead Rhyolite (Upper Miocene)
Light gray to white rhyolite lavas and associated pyroclastic deposits, typically crystal-poor, with sparse phenocrysts of quartz, sanidine and biotite. Lavas typically have a high-aspect ratio and erupted along N-Strending or NE-SW- trending structures. Some rhyolites of this unit, including two domes just north and west of Tres Cerros, are moderately crystal rich, with abundant quartz and sanidine phenocrysts and lesser amounts of biotite. Most of the lavas from this episode of volcanism occur in the southeast portion of the quadrangle, possibly related to a batholithic magma chamber emplaced at approximately 6.8 Ma (Justet, 1999; Justet and Spell, 2001). The most voluminous and contiguous outcrops of this unit are exposed in Peralta Canyon, where hydrothermal alteration is locally pervasive. A rhyolite lava located east of Tres Cerros (0361690 3950778) has an $^{40}Ar/^{39}Ar$ date of 6.86 ± 0.28 Ma on sanidine and a rhyolite lava north of Paliza Canyon has an $^{40}Ar/^{39}Ar$ age of 6.66±0.61 Ma on biotite. Cerrito Yelo is the

youngest phase of Bearhead volcanism at 6.04 ± 0.06 to 6.16±0.03 Ma (Justet and Spell, 2001). Maximum thickness exceeds 150 meters. *GRI Source Map ID 6630* (OF-GM 74).

Ttxc - Basaltic andesite of Thirty-One Draw, cinder deposits (Pliocene)

Pyroclastic deposits, predominantly scoria and spatter agglutinate which may not represent immediate proximity to eruptive vent. Deposits are thin and discontinuous. *GRI Source Map ID 75593* (SIM 3179).

Ttx - Basaltic andesite of Thirty-One Draw, lava flows (Pliocene)

Medium-gray to dark-gray basaltic andesite lava flows (52–53 weight percent SiO_2) underlying vegetated north slopes of Twin Hills. Lava flows are thin, (less than 3 m), vesicular, aphyric to sparsley phyric containing small olivine phenocrysts (less than 1 mm) in a fine-grained, holocrystalline groundmass. Preserved lava flow directions are to the north. Maximum exposed thickness is 50 m. *GRI Source Map ID 75593* (SIM 3179).

Tayc - Basalt of Caja del Rio, cinder deposits (Pliocene)

Multiple dissected cinder cones composed of near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material. *GRI Source Map ID 75593* (SIM 3179).

Tay - Basalt of Caja del Rio, lava flows (Pliocene)

Thin (<4 m), medium-gray basalt to basaltic andesite (49–53 weight percent SiO_2) lava flows exposed in the uppermost reaches of Arroyo Calabasas. Sparsely phyric with olivine phenocrysts (1–2 mm) in microcrystalline groundmass. Ubiquitous, resorbed plagioclase xenocrysts are typically 2–3 mm but can be up to 0.5 cm. *GRI Source Map ID 75593* (SIM 3179).

Tmc - Basalt of Montoso Peak, cinder deposits (Pliocene)

Dissected monogenetic cinder cone composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. Volcanic bombs are common near the summit of Montoso Peak. *GRI Source Map ID 75593* (SIM 3179).

Tmpb - Basalt of Montoso Peak, lava flows (Pliocene)

Tm - Lava flows (Pliocene)
Dark-gray to medium-gray basalt (49–52 weight percent SiO_2) lava flows, typically less than 5 m thick containing common phenocrysts of olivine, pyroxene and plagioclase, and locally xenocrysts of quartz and hornblende. *GRI Source Map ID 75593* (SIM 3179).

Tcpc - Andesite of Cerrita Portillo, cinder deposits (Pliocene)

Near-vent pyroclastic deposits, predominantly spatter with lesser amounts of scoria. *GRI Source Map ID 75593* (SIM 3179).

Tcp - Andesite of Cerrita Portillo, lava flows (Pliocene)

Medium-gray massive, blocky andesite lava flows (58–61 weight percent SiO_2) erupted from vents in the central part of the map area. Lava flows form broad surfaces on lava-flow sequences as much as 100 m thick. Lava flows contain ubiquitous phenocrysts of hornblende, plagioclase, clinopyroxene, Fe-Ti oxides, and minor olivine. Resorbed plagioclase xenocrysts are commonly associated with glomerocrysts of altered pyroxene. Dominant flow directions are to the northeast, east and southeast. *GRI Source Map ID 75593* (SIM 3179).

Tbclc - Basaltic andesite of Arroyo Calabasas, cinder deposits (Pliocene)

Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material preserved at Cerrito Pelado. Active quarry operations have removed and (or) recontoured the northeastern third of Cerito Pelado exposing interbedded flow material and pyroclastic material and lesser intrusive dikes too small to show at map scale. *GRI Source Map ID 75593* (SIM 3179).

Tbclf - Basaltic andesite of Arroyo Calabasas, lava flows (Pliocene)

Medium- to dark-gray, basaltic andesite (53–55 weight percent SiO_2) lava flows containing sparse olivine phenocrysts in a fine-grained holocrystalline groundmass. Lava flows are typically discontinuous and thin, typically less than 1.5–2 m thick. In most places the map unit represents flow lobes of a single flow or eruptive event. The source area is inferred to be the vent area of Cerrito Pelado, based on geochemical and paleomagnetic correlation with lava flows in Arroyo Calabasas. *GRI Source Map ID 75593* (SIM 3179).

Tb - Basalt of La Bajada Rim (Pliocene)

Tb - Basalt of La Bajada rim (Pliocene)
Medium- to dark-gray basaltic (48–50 weight percent SiO_2) lava flows exposed principally along topographic rim of the La Bajada fault escarpment in the southeast part of the map area. Lava flows occur locally to the west of the escarpment in the hanging wall of the La Bajada fault. Includes both tholeiitic and transitional olivine basalts and locally basaltic andesites. Phenocrysts include olivine + pyroxene ± plagioclase and lesser iron-titanium oxides. Locally overlies paleochannel deposits of the Rio Grande. Likely erupted from buried and (or) eroded volcanic centers overlain by units Qcu. Maximum exposed thickness is 40 m. *GRI Source Map ID 7228* (SIM 3194).

Tb - Basalt of La Bajada Rim (Pliocene)
Medium- to dark-gray basaltic (48–50 weight percent SiO_2) lava flows exposed only in the lower reaches of Arroyo Tetilla in the southeast part of the map area. Includes both tholeiitic and transitional olivine basalts and locally basaltic andesites. Phenocrysts include olivine+pyroxene±plagioclase and lesser iron-titanium oxides. Locally overlies paleochannel deposits of the Rio Grande east of the map area in the Cochiti Dam quadrangle. Likely erupted from buried and (or) eroded volcanic centers overlain by Tca. Maximum exposed thickness is 40 m. *GRI Source Map ID 75593* (SIM 3179).

Tb - Basalt flows, thin hydromagmatic deposits, and agglomerate (Upper Pliocene)
Olivine basalt and thin, underlying hydromagmatic deposits exposed in the southeast part of map area (referred to as “Otowi flow” by Galusha and Blick (1971), because of proximity to Otowi bridge). Interlayered with the Puye Formation. Source(s) located east or southeast of the map area. $^{40}Ar/^{39}Ar$ age is 2.57 ± 0.02 Ma (WoldeGabriel and others, 1996). Along upper Bayo Canyon, thin (<10 m) flows of tholeiitic basalt, breccia, and palagonitic pillow basalt erupted from buried sources to the west overlie

lacustrine clays and axial river gravel of the Puye Formation. Lies beneath thin lacustrine beds and fluvial deposits. Age of the tholeiitic flows unknown, but flows in a similar stratigraphic position in the White Rock quadrangle gave $^{40}Ar/^{39}Ar$ ages of about 2.35 ± 0.1 Ma (Dethier, 1997). *GRI Source Map ID 6547* (MF 2419).

Tbsc - Basalt of Tsinat Mesa, cinder deposits (Pliocene)

Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material. *GRI Source Map ID 75593* (SIM 3179).

Tbs - Basalt of Tsinat Mesa, lava flows (Pliocene)

Medium-gray basalt to basaltic andesite (51–53 weight percent SiO_2) lava flows containing small olivine phenocrysts and common resorbed plagioclase and quartz xenocrysts. Commonly interbedded with scoria and cinders. *GRI Source Map ID 75593* (SIM 3179).

Tbcc - Basaltic andesite of Cerro Micho, cinder deposits (Pliocene)

Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material. *GRI Source Map ID 75593* (SIM 3179).

Tbc - Basaltic andesite of Cerro Micho, lava flows (Pliocene)

Medium- to dark-gray, thin (<3m) basaltic andesite (52–53 weight percent SiO_2) lava flows. Contains abundant olivine and lesser pyroxene phenocrysts (< 2 mm) and ubiquitous plagioclase and quartz xenocrysts in a fine grained holocrystalline groundmass. *GRI Source Map ID 75593* (SIM 3179).

Tbhm - Hydromagmatic deposits (Pliocene)

Bedded to massive fall, surge, and flowage deposits composed of basaltic tuff and cinders, accidental fragments of the Santa Fe Group and thin (<10 m), interlayered basaltic flows. Thickest exposures are along Arroyo Montoso and along the Rio Grande south of Alamo Canyon. Ash-fall beds 0.3–3.0 m thick, composed mainly of ash and lapilli containing sparse bombs of accidental and basaltic fragments. Surge beds are planar and cross-bedded, locally rippled, coarse silt to pebbly sand, generally 0.1–0.4 m thick. Flowage deposits mainly matrix-rich pebble to boulder gravel in discontinuous beds 1 to 4 m thick. Near maars the frequency of accidental fragments decreases up-section. Locally sheared, slumped or brecciated. Thickness of fragmental flow deposits and interlayered basalt flows ~60 m along Arroyo Montoso (Self and others, 1996). Interlayered with Pliocene basalt flows and generally lies above Pliocene axial deposits of the Santa Fe Group. Lies beneath flows of basalt and andesite. Older than ~2.5 Ma; maximum age not closely constrained. *Note: Symbol in source data is Tbm. GRI Source Map ID 7228* (SIM 3194).

Tbcl - Basalt of Cochiti Lake (Pliocene)

Tbc - Basalt of Cochiti Lake (Pliocene)
Dark gray basalt lava flows (48–49 weight percent SiO_2) preserved as prominent benches west of the Rio Grande, northeast of the community of Cochiti Lake. Lava flows are typically 1.5 to 2 m thick, having massive interiors and vesicular, rubbly flow bases and tops and contain small (<1 mm) phenocrysts of olivine and pyroxene in a fine grained to microcrystalline groundmass. Locally contains xenoliths of

rounded Precambrian pebbles, likely recycled from underlying Santa Fe Group sediments. Normal polarity based on magnetic fluxgate determinations. Maximum exposed thickness is 70 m. *Note: Symbol in source data is Tbc. GRI Source Map ID 7228* (SIM 3194).

Tcac - Andesite of Colorado Peak, cinder deposits (Pliocene)

Dissected summit cone composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material. Near-vent deposits are sparsely olivine and pyroxene phyric and contain few xenocrysts. *GRI Source Map ID 75593* (SIM 3179).

Tca - Andesite of Colorado Peak, lava flows (Pliocene)

Tca - Andesite of Colorado Peak (Pliocene)
Andesitic lava flows grade transitionally into predominantly near-vent pyroclastic deposits near the summit and dissected southern flank of Colorado Peak, east of the map area on the Montoso Peak 7½-minute quadrangle. Most flows appear to have erupted from a central vent area characterized by a conspicuous summit crater and associated ring dikes and incipient flow breccias. Summit area is cut by northeast- and northwest-trending dikes. Dark-gray basaltic andesite to andesite (56–62 weight percent SiO_2) lava flows up to 15 m thick containing phenocrysts of olivine and pyroxene and abundant xenocrysts of resorbed plagioclase and sparse quartz. Lava flows are lobate in form and directed predominantly to the west and northwest but truncated and offset to the west by down-to-west Cochiti normal fault located on the Montoso Peak quadrangle. An $^{40}Ar/^{39}Ar$ isotopic age of 2.60±0.10 Ma was obtained from a lava flow near the summit of Colorado Peak east of the map area (sample 96TMP38). Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 75 m, but exceeds 225 m to the east on the adjacent Montoso Peak quadrangle. *GRI Source Map ID 7228* (SIM 3194).

Tca - Lava flows (Pliocene)
Dark-gray basaltic andesite to andesite (56–62 weight percent SiO_2) lava flows up to 15 m thick containing phenocrysts of olivine and pyroxene and abundant xenocrysts of resorbed plagioclase and sparse quartz. Lava flows are lobate in form and directed predominantly to the west and northwest but truncated to the west by offset along the down-to-west Cochiti Cone normal fault. *GRI Source Map ID 75593* (SIM 3179).

Tat - Andesite of Tetilla Peak (Pliocene)

Massive light-gray lava flows that underlie the southern rim of Arroyo Colorado in the southwest part of map area and most of Tetilla Peak to the south in the adjacent Tetilla Peak quadrangle (Sawyer and others, 2002). Basaltic andesite and andesite lava flows (56.5–62.7 percent SiO_2) contain common plagioclase and clinopyroxene phenocrysts, sparse xenocrystic quartz, and hornblende that locally is a prominent phenocryst in upper part of lava flows at Tetilla Peak (Zimmerman and Kudo, 1979). An $^{40}Ar/^{39}Ar$ isotopic age of 3.04±0.21 Ma from a lava flow in the adjacent Tetilla Peak quadrangle. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Individual flows range from 50 to 70 m in thickness; aggregate thickness as much as 200 m. *GRI Source Map ID 75593* (SIM 3179).

Tas - Andesite of Sanchez Canyon (Pliocene)

Medium gray to reddish brown (56 weight percent SiO_2) andesite lava flows and associated near vent pyroclastic deposits exposed along the Rio Grande principally between Bland Canyon on the south and Capulin Canyon on the north. Locally includes oxidized andesitic scoria, breccia, spatter and spatter

agglutinate interbedded with lava flows, particularly well preserved in the lower reaches of Bland Canyon where deposits may represent deeply dissected near vent deposits. Lava flows are discontinuous and variable in thickness from 1.5 to 10s of meters thick depending on local underlying paleotopography. Porphyritic lavas contain phenocrysts of olivine + pyroxene ± plagioclase in a fine-grained matrix. Locally, partially resorbed xenocrysts of plagioclase and quartz are present. Maximum thickness is 100 m. *GRI Source Map ID 7228* (SIM 3194).

Tcmc - Andesite of Cerro Micho, cinder deposits (Pliocene)

Near-vent pyroclastic deposits, predominantly scoria, spatter and lesser agglutinate. *GRI Source Map ID 75593* (SIM 3179).

Tcm - Andesite of Cerro Micho, lava flows (Pliocene)

Tcm - Andesite of Cerro Micho (Pliocene)
Lava flows and associated near-vent deposits erupted from several eroded vent areas, the largest of which is preserved at Cerro Micho on the adjacent Montoso Peak quadrangle to the east. Thick lava flows up to 8–10 m, underlie the eastern rim of White Rock Canyon in the northwest part of the map area. Between White Rock Canyon and Arroyo Montoso, the section is exposed in several, down-to-west fault blocks. Scattered near-vent deposits, predominantly cinders, overlie associated lava flows and are thickest along a northwest-southeast trending alignment of dissected cinder and spatter cones extending from the northwest corner of the map to Cerro Micho. Medium-gray to reddish brown andesite (57–60 weight percent SiO_2) lava flows. Although variable, most lava flows characteristically contain olivine and clinopyroxene phenocrysts, sparse to abundant plagioclase phenocrysts ± resorbed plagioclase xenocrysts in a fine-grained holocrystalline groundmass. Near-vent deposits at scattered localities along White Rock Canyon are reddish-brown pyroclastic deposits, predominantly scoria, spatter and lesser agglutinate. An $^{40}Ar/^{39}Ar$ isotopic age of 2.76±0.03 Ma (sample 3MRG5) was obtained from a lava flow in a tributary to Arroyo Montoso. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 300 m although thickness varies considerably and likely reflects eruption of lava flows onto an irregular paleotopographic surface. *GRI Source Map ID 7228* (SIM 3194).

Tcm - Source Name (Pliocene)
Medium-gray to reddish brown andesite (57–60 weight percent SiO_2) lava flows. Although variable, most lava flows characteristically contain olivine and clinopyroxene phenocrysts, sparse to abundant plagioclase phenocrysts ± resorbed plagioclase xenocrysts in a fine-grained holocrystalline groundmass. *GRI Source Map ID 75593* (SIM 3179).

Taba - Andesite and basaltic andesite, undivided (Pliocene)

Undifferentiated lava flows and some interbedded pyroclastic and (or) hydromagmatic deposits preserved in White Rock Canyon north of Arroyo Montoso. Deposits locally include andesite and basaltic andesite lava flows and associated breccias overlying hydromagmatic deposits of unit Tbhm and underlying lava flows of unit Tcm. Maximum exposed thickness is 130 m. *Note: Symbol in source data is Ta. GRI Source Map ID 7228* (SIM 3194).

Tbi - Bearhead Rhyolite, intrusions (upper Miocene)

Tbi - Bearhead rhyolite (Upper Miocene)
White to light gray rhyolite dikes, plugs and stocks. Contain 1-3% phenocrysts of quartz, sanidine,

biotite, ±minor plagioclase. Commonly displays intense, vertically oriented platy cleavage. Vitrophyre typical near margins. Present along and at the intersection of N-S and NE-SE striking faults. *GRI Source Map ID 7218* (OF-GM 85).

Tbi - Bearhead Ryolite intrusives (Upper Miocene)
White to light pink dikes and plugs of rhyolite. 1-3% phenocrysts include quartz, sanidine, biotie and minor plagioclase. *GRI Source Map ID 6630* (OF-GM 74).

Tkpt - Bearhead Rhyolite, Peralta Tuff Member (Miocene)

Tbp - Rhyolite intrusive rocks (Bearhead Rhyolite) (Miocene)
White to gray dikes, plugs, sills, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing sparse phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units are generally flow-banded; width of individual dikes shown on map are commonly exaggerated and may consist of many smaller sub-parallel dikes; associated lithic-rich tuffs (Tbp) occur only in southwest part of map in Aspen Peak area; pervasive, hydrothermally altered plugs and dikes occur throughout west and southwest map area probably emanating from shallow underlying pluton; intrudes or overlies other Paliza Canyon Formation rocks; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); $^{40}Ar/^{39}Ar$ date on intrusion north of Aspen Peak is 6.76 ± 0.10 Ma; date on Cougar Hill plug is 6.80 ± 0.05; date on Rabbit Hill dome is 6.65 ± 0.03 (Justet, 1996); maximum observed thickness about 170 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkpt - Peralta Tuff Member of Bearhead Rhyolite (Miocene)
White to tan, lithic-rich ash-fall tuff; pumice fragments contain phenocrysts of quartz, potassium feldspar, biotite+plagioclase; lithic fragments consist of volcanics from nearby sources. Tkpt fills in rugged volcanic topography on earlier Keres Group rocks; sources for all tuff units unknown; K-Ar age of lowermost tuff bed at Peralta Canyon type locality 6.81±0.15 Ma; maximum observed thickness about 170 m. *GRI Source Map ID 7228* (SIM 3194).

Tbp - Bearhead Rhyolite (Miocene)
White to gray intrusions, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing rare phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units are generally flow-banded; associated lithic-rich tuffs (Tbp) occur only in extreme southeast part of map; small, hydrothermally altered plugs and dikes occur along fault zones in southeast map area; intrudes or overlies all other Keres Group rocks; apparently surrounded by Tpv in south-central map area; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); $^{40}Ar/^{39}Ar$ date on unnamed dome in uppermost San Juan Canyon is 6.38 ± 0.09 Ma (Justet, 1996); maximum observed thickness about 170 m. Two $^{40}Ar/^{39}Ar$ dates on the faulted rhyolite south of Cerro Pelado range from 7.6 to 7.8 Ma (W. McIntosh and L. Peters, NMBGMR). *GRI Source Map ID 7226* (OF-GM 111).

Tbp - Bearhead rhyolite, Peralta tuff member (Upper Miocene)
White to tan to pale pink, pyroclasticfall, flow, and surge deposits interbedded with gray to tan sandy gravel. Pyroclastic deposits consist of pumice and ash of crystal-poor rhyolite containing less than 3% phenocrysts of quartz, sanidine, biotite, and plagioclase. Typically contains abundant (10%) lithic clasts of dominantly andesite and rhyolite lava with lesser amounts of dacite and basalt lava. Sedimentary layers contain exclusively volcanic clasts, which are predominantly glassy and devitrified rhyolite, with variable amounts of intermediate-composition rocks from the older Paliza Canyon formation.

Sedimentary strata are thickest near the base of the unit in Bland Canyon, and are restricted to the Bearhead basin (Smith, 2001) between Peralta and Bland Canyons. The stratigraphy of the Peralta Tuff is described by Smith (2001). Forms tent rocks locally. Erupted between about 6.2-7.0 Ma (Smith, 2001). Thickness in the map area is about 500 m. *GRI Source Map ID 7218* (OF-GM 85).

Tbp - Peralta Tuff Member of the Bearhead Rhyolite (Upper Miocene)
Lithic-rich tuffs and minor tuff breccias. Typically white to beige, poorly-welded with sparse phenocrysts of quartz, biotite, plagioclase, and quartz. The most voluminous and widespread tuff of this unit occurs along the footwall of the Yelo fault, extending to the NE towards Bear Peak on the Cañada quadrangle. Pumice from the tuff of Cerrito Yelo on the Cañada quadrangle is 6.29 ± 0.08 Ma. At Cerrito Yelo this tuff is overlain by a younger, phenocryst-rich rhyolite lava. Preliminary correlation of this tuff on the west side of the Yelo fault is stratigraphically above dacite lavas in the vicinity of Ruiz Peak and intercalated with andesite flows on the east side of Tres Cerros. Exposures of this tuff east of Ruiz Peak are strongly bedded with large (> 1 meter) and abundant lithics, suggesting a nearby source. Maximum thickness of this unit exceeds 70 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tsf - Santa Fe Group, undivided (Miocene)

Ts - Sandstone (Miocene)
White to tan to very pale green feldspathic sandstone; generally medium-grained, well-sorted and well-indurated; grains are mostly subangular to subrounded and consist of roughly 65 to 90% quartz, 5 to 20% feldspar and a variety of other minerals and volcanic rock fragments; much of the quartz is polycrystalline; dark mineral laminations, which may represent bedding are found in scattered locations and have a consistent dip of 15 ± 5° east; feldspar grains are altered to illite and kaolinite (Bundy, 1958); cement consists of variable amounts of chalcedony, calcite, illite, chlorite, limonite, and hematite; near monzonite bodies the quartz grains are partially recrystallized; overlies altered volcaniclastic sediments (Tpv) north of Washington Hill; overlies basaltic andesite lava and altered volcanic breccia just south of map area; underlies andesite on northeast wall of lower Bland Canyon; intruded by monzonite stock and dikes in Bland area; underlies and is interbedded with basalt and andesite west of map area (Goff et al., 2005); underlies andesite, dacite, and rhyolite tuff, and overlies Gallisteo Formation in St. Peter's Dome area east of map (Goff et al., 2002); maximum observed thickness roughly 200 m. Age range of unit is roughly 9 to 18 Ma . *GRI Source Map ID 7225* (OF-GM 112).

Tsf - Undivided Santa Fe Group (Pliocene to Upper Miocene)
White, tan and pink, moderately lithified, planar-bedded to massive silty sandstone, siltstone, and cross-bedded pebbly sand in sparse channels. Sandstone beds up to 4 m thick; channels <1 m. Coarse units locally cemented with sparry calcite. Clasts mainly: (1) intermediate volcanic rocks and quartzite from southern Colorado and the northern Sangre de Cristo Range, and (2) Precambrian granite and associated rocks from the southern Sangre de Cristo Range. Matrix arkosic. Locally beneath tuffs of Canovas Canyon (Tcct) and unconformably overlies Galisteo Formation (Tgs) in the northwestern map area. Dips gently (<8°) to the west and northwest. Correlates, in part, with the Tesuque Formation of Galusha and Blick (1971), and the Ancha Formation of Spiegel and Baldwin (1963). Thickness >100 m. *GRI Source Map ID 7228* (SIM 3194).

Tsf - Santa Fe Group, undivided (Miocene)
Sandstone, siltstone, and conglomerate; relations with underlying Abiquiu Formation unclear; age roughly bracketed between 10 and 20 Ma; maximum observed thickness immediately southeast of map area is roughly 60 m; unit in VC-2B core hole is possibly Ojo Caliente Sandstone and is 48 m thick (Goff and Gardner 1994); unit in Redondo Creek geothermal wells as much as 262 m thick (Nielson and Hulen 1984). *GRI Source Map ID 75592* (GM 79).

Tsf - Santa Fe Group (Miocene)

Poorly exposed pale tan to pink sandstone and dark gray conglomerate; sandstone is generally well-sorted and usually non-indurated; grains are usually well-rounded and consist of weathered mafic volcanic rocks, plagioclase, altered olivine, weathered pyroxene and minor quartz; cement if present is calcite, silica, and Fe-oxides; conglomerate contains basalt and andesite pebbles and cobbles in a sandy matrix; beds too thin to map occur with basalt (Tpb) in area around Las Conches; underlies andesite (Tpa) in upper south wall of East Fork Canyon; underlies basalt in San Juan Canyon north of Cerro del Pino; relations with underlying Abiquiu Formation unclear; maximum observed thickness roughly 60 m; K-Ar date on basalt interbedded with upper Santa Fe Group east of map area is 16.5 ± 1.4 Ma (Gardner and Goff, 1984; Goff et al., 1990). *GRI Source Map ID 7226* (OF-GM 111).

Tsf- Sandstone (Miocene)
White, silicified and metamorphosed fine-grained, well-sorted, sandstone. Consists of ~90% quartz with minor feldspar and lithic fragments. Mostly massive but locally includes faint horizontal and cross bedding. Based on grain size, composition, and lack of associated mudstone, the sandstone is tentatively correlated to middle Miocene eolian sandstones, such as the Zia sandstone, in the Albuquerque basin, and the Ojo Caliente sandstone Member of the Tesuque formation, in the Espanola basin. Stein (1983) and Smith (2001) interpret as roof pendants within stocks of unit Tm. Maximum thickness is 100 m. *GRI Source Map ID 7218* (OF-GM 85).

Tsfu - Santa Fe Group, undivided (middle to late Miocene)
White to tan to pale green, massive to well-bedded sandstone and siltstone; contains minor gravel beds; local areas nonindurated; sand grains consist primarily of quartz and feldspar; beds generally dip to northwest and west; locally contains flows, pillows, and palagonite tuffs of alkali basalt (Tstb); unconformably overlain by mafic hydromagmatic deposits of the Cerros del Rio volcanic field near the mouth of Frijoles Canyon; unconformably overlain by the Keres Group east of St. Peter's Dome; unconformably overlies the Galisteo Formation; estimated age near mouth of Frijoles Canyon is pre-mid-Pliocene (Dethier, 1997); age in St. Peter's Dome area is mid-Miocene (Goff et al., 1990); maximum observed thickness about 100 m. *GRI Source Map ID 7224* (OF-GM 42).

Tsf - Santa Fe Group, undivided (Pliocene to middle(?) Miocene)
Light-brown to white, moderately lithified, massive, planar- and cross-bedded silty to coarse sandstone, red to green siltstone, and cross-bedded pebbly sand in sparse channels. Sandstone beds as thick as 4 m; channels thinner than 1 m. Coarse units locally cemented with sparry calcite. Clasts include silicic to intermediate volcanic rocks and quartzite from southern Colorado and the northern Sangre de Cristo Range and pink granite, pegmatite, and sparse sedimentary rocks from the southern Sangre de Cristo Range. Matrix arkosic. Thickness exceeds 100 m. Lies unconformably beneath the Puye Formation north of Garcia Canyon; the angular unconformity is well exposed between the Puye road and the mouth of Santa Clara Canyon. South of Chupaderos Canyon and west of 106° 09.5' W. long in Santa Clara Canyon, light-colored unlithified to slightly lithified upper Santa Fe is rich in gravel derived from northern sources and contains beds and lenses of dacitic boulder gravel derived from the Jemez Mountains. Paleocurrent directions mainly to the southwest and west, but locally to the south. Dips 4°–6° west and northwest, locally more than 12° near faults in Santa Clara Canyon. Correlates, in part, with the Chamita and Tesuque Formations of Galusha and Blick (1971). Age not well defined, but pre-middle Pliocene. *GRI Source Map ID 6547* (MF 2419).

Tstv - Volcaniclastic sediments (Miocene to upper Oligocene)

Exposures of flow and pillow-palagonite tuff east of St. Peter's Dome of black alkali basalt containing small phenocrysts of iddingsitized olivine, clinopyroxene, and plagioclase in intersertal groundmass of plagioclase, opaque minerals, and glass; glass devitrified and altered to clay; most vesicles filled with calcite; interbedded with Santa Fe Group; ages of interbedded basalt lava south of St. Peter's Dome are of 20.83 ± 0.63 Ma and 25.48 ± 0.84 Ma ($^{40}Ar/^{39}Ar$ ages; WoldeGabriel, 2006). The basalt is underlain

by conglomeratic sandstone with sparse pebble-sized, angular volcanic clasts; thicknesss about 3 m. *GRI Source Map ID 7224* (OF-GM 42).

Tscv - Chamita Formation, lower Vallito Member (Miocene)

Buff colored, strongly to weakly cemented fine to coarse grained sandstone. Locally cross-bedded to planar laminated, otherwise massive. Contains two light gray to white chert beds in the lower 100 m. Interbedded with tephras from the Canovas Canyon Formation in the upper 20 m of the unit. 250 m thick. *GRI Source Map ID 7224* (OF-GM 42).

Tscu - Chamita Formation, Hernandez Member (Miocene)

Thick sequence of sedimentary deposits dominated by arkosic sandstone but containing interbeds of pebbly conglomerate, debris flows, and breccias with subangular clasts of intermediate-composition volcanic rocks (Gardner and Goff 1996); locally altered to silica, iron oxides, clays, and chlorite; may be equivalent to the Hernandez Member of the Chamita Formation as implied by temporal constraints; age bracketed between 74 and 8 Ma; maximum thickness >200 m. *GRI Source Map ID 75592* (GM 79).

Tcar - Chamita Formation, axial river sediment (upper middle Miocene to upper Miocene)

Axial river deposits comprised of stacked channel-fills of sandstone and pebbly sandstone intercalated with overbank deposits of claystone, siltstone, and clayey-silty very fine- to fine-grained sandstone. Conglomerate beds are sparse. Sandy channel-fills are broad (typically >10s of meters wide) and exhibit planar-horizontal to cross-stratified, laminated to very thin to medium beds. Stacked channel-fills form amalgamated packages as much as 12 m-thick. Gravelly channel-fills are marked by a variety of bed forms, ranging from planar to lenticular to cross-stratified. Gravels include very fine to very coarse pebbles and cobbles that are subrounded to rounded, very poorly sorted, and commonly clast-supported. Gravel consists of andesite, dacite, and variable quartz (or quartzite) with subordinate rhyolite and tuff; local gravel zones are rich in basalt. Northeast of Buckman Mesa, where the Cejita Member is recognized (Manley, 1976 and 1979; Dethier and Koning, 2007), clast lithologic types are dominated by Paleozoic sandstone, limestone, and siltstone, with 10-50% granite and 5-8% quartzite. Sand is very pale brown to pink to light gray, very fine- to very coarse-grained (mostly fine- to very coarse-grained, subangular to rounded, and well-sorted. Sand contains abundant quartz that is subrounded to rounded and locally frosted and smoky-colored; lithic grains are minor and include 0-5% quartzite, 0-2% green-brown quartz grains (probably derived from erosion of Paleozoic sedimentary rocks), 5% mafic grains, and variable volcanic lithic grains (mostly rhyolite to dacite in composition). Amount of potassium feldspar and granitic gravel increases towards the eastern margin of the unit. Clayey-silty overbank sediment is light brown to very pale brown to pink and well consolidated. Unit includes the Vallito, Hernandez, and Cejita Members of Koning and Aby (2005) and described more in Koning et al. (2007). Unit grades and interfingers eastward with the Cuarteles Member of the upper Tesuque Fm (Ttacu and Ttacuf, not in GRI data) and gradational overlies basin floor deposits (unit Ttb, not in GRI data). The Chama-El Rito Member is inferred to underlie this unit under the Pajarito Plateau. Unit is interpreted to have deposited by a south-flowing, axial river system in the southern Española Basin during 6-13.2 Ma (Koning and Aby, 2005; Koning et al., 2007). Greater than 700 m thick in northwest corner of the map. *GRI Source Map ID 75477* (OFR 531).

Tccu - Chamita Formation, Cuarteles Member (upper middle Miocene to upper Miocene)

Strata similar to that of the Cuarteles Member of the Tesuque Formation (Ttcu), as described above. *GRI Source Map ID 75477* (OFR 531).

Tccuf - Chamita Formation, Cuarteles Member, fine-grained, distal sediment (upper middle Miocene to upper Miocene)

Strata similar to that of fine-grained Cuarteles Member of the Tesuque Formation (Ttcuf), as described above. *GRI Source Map ID 75477* (OFR 531).

Tstb - Tesuque Formation, basalt flow (Miocene to upper Oligocene)

Exposures of flow and pillow-palagonite tuff east of St. Peter's Dome of black alkali basalt containing small phenocrysts of iddingsitized olivine, clinopyroxene, and plagioclase in intersertal groundmass of plagioclase, opaque minerals, and glass; glass devitrified and altered to clay; most vesicles filled with calcite; interbedded with Santa Fe Group; ages of interbedded basalt lava south of St. Peter's Dome are of 20.83 ± 0.63 Ma and 25.48 ± 0.84 Ma ($^{40}Ar/^{39}Ar$ ages; WoldeGabriel, 2006). The basalt is underlain by conglomeratic sandstone with sparse pebble-sized, angular volcanic clasts; thicknesss about 3 m. *GRI Source Map ID 7224* (OF-GM 42).

Tstc - Tesuque Formation, Chama-El Rito Member (Miocene)

Orange to pinkish quartz-rich sandstone with a few thin lenses of volcanic pebbles derived from volcanic fields to the north (Latir). At least 200 m thick. *GRI Source Map ID 7224* (OF-GM 42).

Ttcu - Tesuque Formation, Cuarteles Member (upper middle Miocene to upper Miocene)

Alluvial slope deposits of sandy pebble-conglomerate and pebbly sandstone channel-fill complexes, with subordinate slightly clayey-silty sand containing <5% pebbles that was deposited by lower-energy flow outside of confined channels. We refer to the latter, fine-grained sediment as extra-channel sediment. Bedding within the channel-fill complexes (from most to least common) ranges from lenticular, horizontal-planar, to cross-stratified (up to 20 cm-thick foresets), and generally the beds are very thin to medium (with internal planar-laminations); bedding becomes more horizontal-planar westward where this unit grades into Ttcuf. Relatively narrow, U-shaped channels are locally present. Channel complexes may fine-upwards from gravel- to sand-dominated sediment. Pebble conglomerate is clast-supported and locally has up to 25% cobbles. Pebbles are poorly to moderately sorted and mostly angular to subangular (some subrounded). Clasts are composed of granite with trace to 1% yellowish Paleozoic limestone and siltstone, trace to 1% quartzite, trace chert, 0.5-2% gneiss, and trace to 3% amphibolite. Channel-fill sand ranges from fine- to very coarse-grained but mostly is medium- to very coarse-grained, angular to subrounded (mostly subangular), poorly to moderately sorted, and an arkose. 1-15% of individual channel complexes are strongly to moderately cemented by calcium carbonate, the rest is weakly to non-cemented and loose to weakly consolidated.

Extra-channel deposits consist of slightly clayey-silty (visual estimate of 1-10% fines), very fine-to very coarse-grained sandstone (mostly very fine- to medium-grained) with less than 10% scattered pebbles; generally reddish yellow to pink to light brown in color. Extra-channel sediment is generally massive but may locally be in very thin to thick, tabular beds or be planar-laminated. The sand is poorly to moderately sorted, subangular to subrounded, and an arkose. Within the extra-channel sediment are

minor very thin to thin, lenticular beds of medium- to very coarse-grained, arkosic sandstone and granitic pebble-conglomerate. Locally, paleosols are present that have 10-50 cm-thick calcic horizons with stage I to II+ morphology; also, some paleosols possess 5-15 cm-thick, reddish yellow, Bw or clayey Bt horizons 10-30 cm-thick. Extra-channel sediment has been observed to locally grade laterally into coarse deposits similar to those seen in channel-fills. They are interpreted to represent small, aggradational lobes at the mouths of discontinuous channels.

The Cuarteles Member is considered part of the Tesuque Formation east of the Rio Grande and part of the Chamita Formation west of the Rio Grande (Koning and Aby, 2005; Koning et al., 2005a). Unit gradationally overlies unit Tta and has prograded southward over fluvial deposits of unit Ttcuf. The lower gradation zone of the Cuarteles Member is over 6-12 m thick to the south and becomes thicker to the north. This coarser sediment of the Cuarteles Member grades westward into fine-grained sediment of the distal alluvial slope (included in the Cuarteles Member; unit Ttcuf). The Cuarteles Member is interpreted to have been deposited in an alluvial slope depositional environment; specifically, as channel-fills or small depositional lobes at the mouths of discontinuous channels. An age of 13.2-8 Ma is interpreted based on a synthesis of radiometric ages, biostratigraphy, and geomagnetic polarity studies (further discussed in Koning et al., 2005a; Koning and Aby, 2005). Up to 350 m thick. *GRI Source Map ID 75477* (OFR 531).

Ttcuf - Tesuque Formation, Cuarteles Member, fine-grained, distal sediment (upper middle Miocene to upper Miocene)

Alluvial slope silty-clayey very fine- to medium-grained sandstone, with subordinate siltstone and mudstone. Coarse channel-fills of pebbly sandstone and sandy-pebble-conglomerate comprise about 3-30% of the unit. These coarse channel-fills are scattered, lenticular to ribbon-shaped, and up to 10 to 100 cm-thick; locally, these channel-fills form thicker, multistory complexes. The internal bedding of the channels is very thin to thin, and planar to lenticular to cross-stratified. Pebbles are moderately to poorly sorted, subangular to subrounded, and granitic (with trace to 1% yellowish Paleozoic siltstone and limestone, quartzite, and gneiss). Channel-fill sand is fine- to very coarse-grained, subangular to subrounded, poorly to well sorted, and an arkose. Paleocurrent indicators in the channels indicate westward paleoflow. Channels-fills may fine-upward from pebbly to sandy sediment. Isolated channels tend to be strongly to moderately cemented, whereas laterally extensive and thick channel complexes are generally not as cemented.

Finer-grained sediment outside of coarse-grained channel-fills is in very thin to thick, tabular beds that may be internally laminated. Colors range from pink to light brown to reddish yellow to light yellowish brown. Sand is generally very fine- to medium-grained, well sorted, subangular to subrounded, and an arkose. There is 0.5 to 1%, very thin to thin, brown to light brown (7.5YR 5-6/4) claystone beds. Very thin to medium, ribbon- to lenticular-shaped, isolated channel-fills are present within the finer-grained sediment (generally 3-30% of the volume). Finer-grained sediment is moderately to well consolidated and weakly cemented by calcium carbonate. Coarse white ash and basaltic ash beds are locally present. Unit possesses 1-3% weakly developed paleosols with reddish Bw horizons 20- to 30-cm thick.

The Cuarteles Member is considered part of the Tesuque Formation east of the Rio Grande (Ttcu) and part of the Chamita Formation (Tccu) west of the Rio Grande (Koning and Aby, 2005; Koning et al., 2005a). Unit grades laterally westward into axial river sediment (Tcar) and has also prograded westward over axial river sediment. This unit grades upward and laterally eastward into coarser sediment of the Cuarteles Member (Ttcu). This finer-grained part of the Cuarteles Member is interpreted to represent a generally low-energy alluvial environment where the distal alluvial slope transitioned to the flat basin floor. An age of 13.2-8 Ma is interpreted based on a synthesis of radiometric ages, biostratigraphy, and geomagnetic polarity studies (further discussed in Koning et al., 2005; Koning and Aby, 2005). 350-400 m-thick. *GRI Source Map ID 75477* (OFR 531).

Tsfb - Basalt flows and cinders (late Miocene)

Tsfb - Basalt flows in Santa Fe Group (Miocene)
Thin discontinuous flows, pillow basalt and palagonite tuff composed of black alkali basalt and basanite containing small phenocrysts of olivine ± clinopyroxene ± plagioclase; vesicles commonly filled with calcite; olivine may be altered to iddingsite; basalts occur in upper exposures of Santa Fe Group on lower south and east flanks of St. Peters Dome (Frijoles 7½-minute quadrangle); one small intrusive plug of alkali basalt in Galisteo Formation is correlated with this unit; K-Ar age of thin flow in upper Medio Canyon 16.5±1.4 Ma. Maximum observed thickness about 5 m. *GRI Source Map ID 7228* (SIM 3194).

Tsfb - Basalt flows and cinders (upper Miocene)
Olivine basalt and thin cinder deposits exposed in southwest part of map area and at one location in Santa Clara Canyon. Lies above and locally interlayered with Santa Fe Group; underlies Puye Formation. $^{40}Ar/^{39}Ar$ ages from flows exposed along Bayo Canyon and in an unnamed canyon to the south are 8.86 ± 0.05 and 8.78 ± 0.09 Ma, respectively (WoldeGabriel and others, 2001). *GRI Source Map ID 6547* (MF 2419).

Tscc - Cerro Conejo Formation (Miocene)

Dark gray to black, aphyric to phenochyst poor basalt with rare phenocrysts of olivine and plagioclase. Chamberlin and McIntosh (2007) determined a $^{40}Ar/^{39}Ar$ age of 9.9±0.9 Ma for this flow based on two samples from the Loma Creston quadrangle to the south. Justet (2003) calculated a $^{40}Ar/^{39}Ar$ age of 10.96±0.29 for the flow exposed in Borrego Canyon in the southwestern corner of the quadrangle. *GRI Source Map ID 6630* (OF-GM 74).

Tqv - Quartz veins (Miocene)

Consists of quartz veins and vein networks up to 50 m wide cutting altered Bearhead Rhyolite and Keres Group volcanic rocks; veins exposed primarily along fault zones in southwest map area; both units have been modified by post-emplacement faulting; veins contain minor adularia, Cu-Pb-Zn sulfides and gold-silver electrum; sulfides extensively altered to oxides, alunite and clay; units are probably between 5.6 and 8.5 Ma (WoldeGabriel and Goff, 1989); Vertical extent of veins exceeds 250 m (Bundy, 1958). *GRI Source Map ID 7225* (OF-GM 112).

Tghd - La Grulla Formation, hornblende dacite and rhyodacite (Miocene)

Massive to sheeted, porphyritic lavas of diverse texture capping Cerro de la Garita and other hills; flows have distinctive hornblende, plus plagioclase, sanidine, biotite, and minor clinopyroxene phenocrysts; erupted from several vents on southeastern La Grulla Plateau; 40Ar/39Ar ages range from 727 to 763 Ma (Kempter et al. 2007; Kelley et al., in press); maximum exposed thickness is 30 m. *GRI Source Map ID 75592* (GM 79).

Tgbhd - La Grulla Formation, porphyritic biotite, hornblende rhyodacite (Miocene)

Massive to sheeted, extremely porphyritic lava on north caldera rim having phenocrysts of sanidine, plagioclase, resorbed quartz, biotite, hornblende, clinopyroxene, orthopyroxene, and opaque oxides; contains rare iddingsitized olivine crystals and plagioclase-pyroxene-biotite clots; displays local hydrothermal alteration to silica, clay, chlorite, and Fe-oxides; 40Ar/39Ar age is 742 ± 0.05 Ma (Kelley

et al., in press); maximum exposed thickness about 135 m. *GRI Source Map ID 75592* (GM 79).

Tgb - La Grulla Formation, olivine basalt (Miocene)

Two exposures of massive lava on northwestern caldera rim informally correlated with the basalt of Encino Point (Kelley et al. 2007; Lawrence 2007); contain small phenocrysts of olivine, plagioclase, and clinopyroxene; interlayered with La Grulla Plateau andesite; 40Ar/39Ar ages are 780 ± 0.13 Ma (lower basalt) and 779 ± 0.09 Ma (upper basalt, Kelley et al., in press); maximum exposed thickness is roughly 35 m. *GRI Source Map ID 75592* (GM 79).

Tga - La Grulla Formation, porphyritic andesite and dacite, undivided (Miocene)

Massive to sheeted, porphyritic lavas with phenocrysts of plagioclase, biotite, clinopyroxene, orthopyroxene, and opaque oxides; may contain plagioclase-pyroxene-biotite clots; erupted from multiple vents; 40Ar/39Ar ages on widely separated samples range from 743 to 781 Ma (Justet 2003; Kempter et al. 2007; Kelley et al., in press); maximum exposed thickness is about 330 m on north caldera wall. *GRI Source Map ID 75592* (GM 79).

Tpgd - Dacite outcrop in Guaje Canyon (Miocene)

Crystal-poor lava with conspicuous phenocrysts of sanidine and numerous felty crystals of amphibole, most of which are altered. Sanidine comprises <3% of the whole rock, while amphibole comprises ~3% of the whole rock. Some quartz is present, but whether these are quartz phenocrysts or silicic vug fill is unclear. Small mafic crystals are also present; these appear to be pyroxenes. A 40Ar/39Ar age of 9.58 ±0.13 Ma was determined for this dacite. *GRI Source Map ID 6633* (OF-GM 55).

Tpv - Paliza Canyon Formation, volcaniclastic member, conglomerate sandstone (Pliocene? to Miocene)

Tpv - Volcaniclastic deposits (Miocene)
Black to gray to pale pink to purple-red, highly diverse volcaniclastic unit consisting predominately of sandstones, gravels, lahars, block-and-ash flows, and other debris flows; mostly formed contemporaneously with Paliza Canyon Formation; locally contains hyper concentrated flow and fluvial deposits, cinder and scoria deposits, and pyroclastic fall deposits; contains andesite and dacite flow and flow-breccias too small or thin to map; older deposits display considerable hydrothermal alteration up to presence of epidote; unit has accumulated in small basins, topographic lows, and canyons cut into Paliza Canyon Formation volcanoes; unit generally thickens to south and east toward evolving Rio Grande rift; most of unit mapped according to the definition of Cochiti Formation described by Bailey et al., (1969) and Gardner et al. (1986) with stratigraphic interpretation extended into the Pliocene (Smith and Lavine, 1996); as defined here, includes both Volcanic Breccia 1 (volcanic sandstone and conglomerate) and Volcanic Breccia 2 (predominately scoria-derived deposits) of Stein (1983) in areas around and north of Bland; largest exposure of Tpv occurs in Cochiti Canyon where predominately lahars and block-and-ash flows are interbedded with small andesite and dacite flows, and with dacite tuffs; scoria-rich deposits occur in Bland Canyon, north of Bruce Place, and in areas of upper Medio Dia Canyon; bedded deposits with consistent 15 to 20° dip to east occur in Colle Canyon; exposure of dacite-rich boulder conglomerate occurs beneath upper Bandelier Tuff at southeast tip of Upper Horn Mesa; interbedded and intruded by all types of Keres Group lavas and dikes; intruded by monzonite in Colle Canyon and upper Bland Canyon; underlies Santa Fe Group sandstone in unnamed canyon north of Bland stock; age of Tpv in map area is bracketed between roughly 8 and 13 Ma; maximum exposed thickness is about 215 m. *GRI Source Map ID 7225* (OF-GM 112).

Tpv - Volcaniclastic member (Pliocene? to Miocene)
Conglomeratic sandstone and sandy conglomerate locally containing cinder deposits, pyroclastic- fall deposits, and lava flows too small or thin to map; unit has accumulated in small basins, topographic lows, and paleocanyons; contemporaneous with eruption of lavas of the Paliza Canyon Formation; upper part of unit may be correlative with oldest Cochiti Formation (Smith and Lavine 1996); maximum exposed thickness about 70 m. *GRI Source Map ID 75592* (GM 79).

Tpy - Volcaniclastic deposits (Pliocene to Miocene)
Black to gray to pale pink volcaniclastic unit consisting predominately of gravels, lahars, block and ash flows, and other debris flows; mostly formed contemporaneously with Keres Group but may extend into Pliocene; locally contains hyper concentrated flow and fluvial deposits, cinder deposits, and pyroclastic fall deposits; contains andesite flow-breccias too small or thin to map; unit has accumulated in small basins, topographic lows, and canyons cut into Keres Group volcanoes; unit generally thickens to south and east toward San Juan and Paliza canyons; most of unit mapped according to the definition of Cochiti Formation described by Bailey et al., (1969) and Gardner et al. (1986) with stratigraphic interpretation extended to Pliocene (Smith and Lavine, 1996); interbedded with Tkpt and Tpa in lower San Juan Canyon; interbedded with Tpa and Tpbhd in southern west wall of Peralta Canyon; overlies Tpa, Tphd and Tpbhd on eastern flanks of Cerro Pelado Ridge; apparently surrounds dome of Tbh in south-central map area; age of Tpv is bracketed between roughly 3 and about 13 Ma; maximum exposed thickness about 70 m. *GRI Source Map ID 7226* (OF-GM 111).

Tpv - Paliza Canyon formation (Miocene)
Volcaniclastic deposits. Coarse-grained volcaniclastic breccia, conglomerate, and sandstone interbedded with thin Paliza Canyon formation lava flows and flow breccias of basalt and basaltic andesite composition. Primarily debris-flow and fluvial deposits consisting of reworked flow-breccia blocks and tephra. Locally includes primary and slightly reworked gray, andesitic tephra and white rhyodacitic and dacitic tephra. Outcrops in Cochiti and Sanchez Canyons include monolithologic breccias with sparse radially-jointed blocks that may be block-and-ash-flow deposits. Stratigraphy, volcanology, and sedimentology of these deposits described by Lavine (1995). *GRI Source Map ID 7218* (OF-GM 85).

Tpv - Volcaniclastic deposits, Paliza Canyon Formation (Miocene)
Volcaniclastic conglomerates, sandstones and silts of mixed provenance. Older sediments of this unit are primarily intercalated with thin basalt flows of the Paliza Canyon Formation and tephras of the Canovas Canyon Rhyolite, whereas the younger gravels are intercalated with andesite and dacite lavas. These gravels thicken to the southwest towards Borrego Mesa and exhibit southeast-trending imbrication. Maximum thickness is approximately 100 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpvs - Paliza Canyon Formation, volcaniclastic member, sandstone (Pliocene? to Miocene)

Tpvs - Volcanic sandstone (Miocene)
Brick red to tan moderately- to well-sorted sandstone containing mostly volcanic fragments, feldspar, mafic minerals, and minor quartz; mapped only where laterally extensive and at least 3 m thick; occurs between lava flow contacts in isolated locations throughout Paliza Canyon Formation. *GRI Source Map ID 7225* (OF-GM 112).

Tpvs - Volcaniclastic member (Pliocene? to Miocene)
Tpvs is a moderately to well-sorted volcaniclastic sandstone that is brick red to tan and contains mostly volcanic fragments, feldspar, mafic minerals, and minor quartz; present between lava flow contacts in isolated locations throughout southeastern part of the map area; mapped only where laterally extensive

and at least 3 m thick. *GRI Source Map ID 75592* (GM 79).

Tpb - Paliza Canyon Formation, olivine basalt and basaltic andesite, undivided (Miocene)

Tpb - Olivine basalt and basaltic andesite, undivided (Miocene)
Flows, flow breccia, spatter deposits, and scoria of basalt and subordinate basaltic andesite from multiple sources; one vent (shown within unit Tpv) occurs at east end of prominent ridge north of Bruce Place; most units are slightly porphyritic; flows dense to highly vesicular; typical basalt contains 5% phenocrysts of olivine and plagioclase (=2 mm) in intersertal groundmass of olivine, clinopyroxene, plagioclase, opaque oxides, and glass; olivine occurs rarely in clots =3 mm in diameter; most olivine has high-temperature iddingsite; some flows have diktytaxitic texture; some flows have clinopyroxene phenocrysts; most flows display variable amounts of hydrothermal alteration consisting of silica, calcite, Fe-oxides, clay ± zeolite ± chlorite ± epidote ± pyrite; interbedded with and underlies Tpa; intruded by monzonite in lower Colle Canyon, upper Bland Canyon and central Medio Dia Canyon; units in map area never dated; maximum exposed thickness about 150 m. *GRI Source Map ID 7225* (OF-GM 112).

Tpb - Olivine basalt and basaltic andesite, undivided (Miocene)
Flows, flow breccia, spatter deposits, and scoria of basalt and subordinate basaltic andesite from multiple vents; most units are slightly porphyritic containing phenocrysts of olivine, plagioclase ± clinopyroxene; displays variable amounts of hydrothermal alteration consisting of silica, calcite, Fe-oxides, clay ± zeolite ± chlorite ± epidote ± pyrite; 40Ar/39Ar ages from western and southern map areas range from 8.88 to 9.45 Ma (Justet 2003; Kelley et al., in press); maximum exposed thickness about 150 m. *GRI Source Map ID 75592* (GM 79).

Tpb - Olivine basalt and basaltic andesite, undivided (Miocene)
Flows, flow breccia, spatter deposits, and scoria of basalt and subordinate basaltic andesite from multiple sources; most units are slightly porphyritic; flows dense to highly vesicular; tends to be relatively fresh in southwest to highly altered in northeast and east; typical basalt contains 5% phenocrysts of olivine and plagioclase (=2 mm) in intersertal groundmass of olivine, clinopyroxene, plagioclase, opaque oxides, and glass; olivine occurs rarely in clots =3 mm in diameter; most olivine has high-temperature iddingsite; some flows have diktytaxitic texture; some flows have clinopyroxene phenocrysts; visible alteration consists of silica, calcite, Fe-oxides, clay ± zeolite ± chlorite ± epidote ± pyrite; interbedded with and underlies Tpa; overlies and possibly interbedded with Santa Fe Group (Tsf); overlies Abiquiu Formation (Ta); composite K-Ar age on similar basalts south of map area is 13.2 ± 1.24 Ma (Gardner and Goff, 1984); 40Ar/39Ar date on basalt east of San Juan Canyon near southwest corner of map is 9.45 ± 0.07 Ma (W. McIntosh and L. Peters, NMBGMR); K-Ar age of hydrothermal clay in altered basalt on NM highway 4 south of Las Conches is 8.05 ± 0.13 Ma (WoldeGabriel, 1990); maximum exposed thickness about 140 m. *GRI Source Map ID 7226* (OF-GM 111).

Tpb - Paliza Canyon formation (Miocene)
Olivine basalt. Contains sparse phenocrysts of plagioclase, augite, and olivine. Exposed in Colle Canyon at northern quadrangle margin. Intruded by Tm. *GRI Source Map ID 7218* (OF-GM 85).

Tpb - Olivine basalt, Paliza Canyon Formation (Miocene)
Black flows and black to red cinder deposits of sparsely porphyritic basalt containing phenocrysts of plagioclase and olivine ± clinopyroxene in an intersertal groundmass of plagioclase, clinopyroxene, olivine, opaque minerals, and glass; olivine generally displays iddingsite alteration; plagioclase may be complexly zoned; may contain sparse plagioclase-pyroxene and olivine-pyroxene clots; flows and cinder deposits have a variety of ages; K-Ar date of lava in bottom of Capulin Canyon north of St. Peter's Dome 11.3±0.9 Ma (Goff et al., 1990); maximum observed thickness about 20 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpb - Basalt, Paliza Canyon Formation (Miocene)
Tpb/Tpbs/Tpbt: Medium to dark gray lavas and associated scoria deposits (Tpbs). Poorly to moderately porphyritic with phenocrysts of plagioclase and pyroxene. Trace amounts of olivine and/or hornblende may be present. Flows are typically flow banded and platey. Brecciated basal and top horizons of flows and vesicular horizons are also common. Most of the flows are intercalated with gravel deposits (Tpb) and appear to have originated along N-S structures related to the western Cocido fault zone, flowing to the southeast. An 40Ar/39Ar date for a flow from the base of this unit is 9.54±0.08 Ma. Maximum thickness of individual flows can exceed 30 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpa - Paliza Canyon Formation, Two-pyroxene andesite, undivided (Miocene)

Tpa - Two-pyroxene andesite, undivided (Miocene)
Domes, flows, flow breccia, spatter deposits, and scoria of andesite from multiple sources; vents are widely scattered; individual units are slightly porphyritic to very porphyritic; flows dense to highly vesicular; tends to be relatively fresh and sometimes glassy in the east to hydrothermally altered in west and southwest; typically contains 20% phenocrysts of plagioclase, orthopyroxene, and clinopyroxene in an intersertal or slightly trachytic groundmass; groundmass usually contains abundant opaque oxides; plagioclase phenocrysts are commonly fritted and complexly zoned; most specimens contain plagioclase-pyroxene clots = 1 mm in diameter; some units contain enclaves of plagioclase-pyroxene a few centimeters in diameter; some flows contain minor hornblende; visible alteration varies from slight to extremely intense; alteration generally consists of silica, calcite, Fe-oxides, clay ± chlorite ± zeolite ± pyrite ± epidote; interbedded with and intrudes most other Paliza Canyon units; overlies basalt in upperBland Canyon and lower Colle Canyon; intruded by monzonite in lower Colle Canyon and at Bland; units in map area not dated; fresh andesite flows in upper part of unit west of map area range from 8.8 to 9.4 Ma (Goff et al., 2005); maximum exposed thickness about 150 m in upper Medio Dia Canyon. *GRI Source Map ID 7225* (OF-GM 112).

Tka - Undivided andesite (Miocene)
Gray to pink to black flows, domes, and minor intrusives of porphyritic andesite containing phenocrysts of plagioclase, clinopyroxene, and hypersthene; flows massive to sheeted; may contain flow breccia; displays pervasive hydrothermal alteration in canyon bottoms; ages of various flows unknown; maximum observed thickness about 50 m. *GRI Source Map ID 7228* (SIM 3194).

Tpa - Two-pyroxene andesite, undivided (Miocene)
Domes, flows, flow breccia, spatter deposits, and scoria of andesite from multiple sources; vents are widely scattered; individual units are slightly porphyritic to very porphyritic containing phenocrysts of plagioclase, orthopyroxene, and clinopyroxene; alteration varies from slight to intense consisting of silica, calcite, Fe-oxides, clay ± chlorite ± zeolite ± pyrite ± epidote; 40Ar/39Ar ages in western and southern map area range from 8.2 to 9.4 Ma (Justet 2003; Kelley et al., in press); maximum exposed thickness about 150 m. *GRI Source Map ID 75592* (GM 79).

Tpa - Keres Group Volcanic Rocks (Miocene)
Dark gray to red (oxidized) intermediate composition lavas exposed in Santa Clara Canyon, Los Alamos Canyon, and the Pine Springs area. The andesite in Santa Clara Canyon is platy, dark gray, and porphyritic with phenocrysts of plagioclase (Woldegabriel et al., 2006). The 40Ar/39Ar age for this andesite is 7.78±0.04 Ma. In Los Alamos Canyon, the porphyritic andesite lava at the reservoir outlet has 20% phenocrysts of plagioclase, clinopyroxene, and othopyroxene and an 40Ar/39Ar age date of 8.72 ± 0.05 Ma (Broxton et al., 2007). This flow also has crystal clots of clinopyroxene, orthopyroxene, and plagioclase. Vesicular facies are common in the Pine Springs area, where four separate outcrops occur, representing two lava types. One appears more dacitic, with larger phenocrysts of plagioclase and lighter color, and one more andesitic, with a dark, fine-grained groundmass with smaller phenocrysts

of plagioclase and pyroxene. WoldeGabriel et al. (2006) report an 40Ar/39Ar age of 11.18±0.13 Ma on an andesite in the southernmost outcrop at Pine Spring. The three northern outcrops are red (oxidized), but the southernmost outcrop is relatively unaltered. Maximum exposed thickness is ~ 40 meters. *GRI Source Map ID 6633* (OF-GM 55).

Tpa - Two-pyroxene andesite, undivided (Paliza Canyon Formation)
Domes, flows, flow breccia, spatter deposits, and scoria of andesite from multiple sources; individual units are slightly porphyritic to very porphyritic; flows dense to highly vesicular; tends to be relatively fresh and sometimes glassy in the west to hydrothermally altered in east; typically contains 20% phenocrysts of plagioclase, orthopyroxene, and clinopyroxene in an intersertal or slightly trachytic groundmass; groundmass usually contains abundant opaque oxides; plagioclase phenocrysts are commonly fritted and complexly zoned; most specimens contain plagioclase-pyroxene clots = 1 mm in diameter; some units contain enclaves of plagioclase-pyroxene a few centimeters in diameter; some flows contain minor hornblende; visible alteration generally consists of silica, calcite, Fe-oxides, clay ± chlorite ± zeolite ± pyrite; underlies Tpbd and Tphd (not in GRI data); interbedded with Tpv, Tpbhd and Tpb; Cerro Pelado ridge is probably the vent area for many of the flows; black porphyritic andesite along crests of Cerro Pelado and Peralta Ridge have Ar 40/39 dates of 8.78±0.14 and 8.85±0.17 Ma; platy andesite midway down west flank of Cerro Pelado is dated at 9.44±0.21 Ma (Justet, 2003); maximum exposed thickness over 310 m near Cerro Pelado. *GRI Source Map ID 7226* (OF-GM 111).

Tpa - Paliza Canyon formation (Miocene)
Flows, domes, and minor intrusives of gray to dark pink to black porphyritic andesite. Also includes associated volcanic breccias, which are especially thick in upper Cochiti Canyon (Lavine, 1995). Contains 1-5% phenocrysts of plagioclase, clinopyroxene, and lesser amounts of hypersthene. Maximum observed thickness about 140 m. Commonly flow banded. *GRI Source Map ID 7218* (OF-GM 85).

Tpa - Andesite, Paliza Canyon Formation (Miocene)
Gray to pink to black flows, domes, and minor intrusives of porphyritic andesite containing phenocrysts of plagioclase, clinopyroxene, and hypersthene in a glassy to almost intersertal groundmass; microphenocrysts consist of plagioclase, clinopyroxene, hypersthene, and opaque minerals; flows massive to sheeted; may contain flow breccia; ages of various flows unknown; maximum observed thickness about 50 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpa - Andesite. Paliza Canyon Formation (Miocene)
Typically medium gray to reddish purple porphyritic lavas and associated pyroclastic deposits. Phenocryst content is typically <20% and includes acicular plagioclase with less abundant pyroxenes (clinopyroxene and/or orthopyroxene). Flow banding is common, as are vesicular and brecciated horizons. Debris flow deposits, typically less than 5 meters in thickness, occur intercalated with lava flows. A thick package of these andesitic units occurs north and east of Tres Cerros, suggesting a source in this vicinity. One distinctive flow, dark gray and very fine-grained with sparse phenocrysts of plagioclase and pyroxene, occurs in numerous outcrops peripheral to Cerrito Yelo. This unit is offset by several faults that radiate from the Cerrito Yelo center and isoverlain by the Peralta Tuff Member of the Bearhead Rhyolite. An 40Ar/39Ar date for a flow near the top of this unit at Tres Cerros is 10.8 ± 1.5 Ma on hornblende. Maximum thickness of this unit exceeds 200 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpbhd - Paliza Canyon Formation, porphyritic biotite, hornblende dacite (Miocene)

Tpbhd - Porphyritic biotite, hornblende dacite (Miocene)
Dome and flow complexes and highly faulted flows containing 10 to 15% phenocrysts of plagioclase,

biotite (=3 mm), oxyhornblende (=5 mm), orthopyroxene, and clinopyroxene, in a trachytic groundmass filled with plagioclase and pyroxene microlites; groundmass also contains apatite microphenocrysts up to 0.5 mm long; plagioclase phenocrysts (=20 mm) are fritted and complexly zoned; contains gray, vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite up to 30 cm in diameter; partially obscured vent occurs beneath southwest flank of Rabbit Mountain; vent for flows east of Bearhead Ridge may occur north of Reid Canyon; fresh outcrops unusual; hydrothermal alteration consists of clay, silica, calcite, Fe-oxides, chlorite ± epidote; interbedded with andesite flows; intruded by Bearhead Rhyolite; 40Ar/39Ar age of dome and flow complex south of Rabbit Mountains is 8.66 ± 0.22 Ma; 40Ar/39Ar age of similar unit west of map area is 9.42 ± 0.22 Ma (Justet, 2003; Goff et al., 2005); age of pervasive hydrothermal alteration of this unit in upper Del Norte Canyon area is about 6.5 to 6.0 Ma (WoldeGabriel and Goff, 1989); maximum exposed thickness is at least 275 m. *GRI Source Map ID 7225* (OF-GM 112).

Tpbhd - Porphyritic biotite, hornblende dacite (Miocene)
Extensive dome and flow complex filling paleocanyon south of Rabbit Mountain; contains large phenocrysts of plagioclase, plus biotite, hornblende, orthopyroxene, and clinopyroxene; contains vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite as large as 30 cm in diameter; hydrothermally altered to clay, silica, calcite, Fe-oxides, chlorite ± epidote; 40Ar/39Ar age is 8.66 ± 0.22 Ma (Kelley et al., in press); exposed thickness at least 275 m. *GRI Source Map ID 75592* (GM 79).

Tpbhd - Porphyritic biotite, hornblende dacite (Miocene)
Extensive dome and flow complex filling east-west trending paleocanyon in southern map area (Smith et al., 1970; Gardner, 1985); contains 15% phenocrysts of plagioclase, biotite (=3 mm), oxyhornblende (=5 mm), orthopyroxene, and clinopyroxene, in a trachytic groundmass filled with plagioclase and pyroxene microlites; groundmass also contains apatite microphenocrysts up to 0.5 mm long; plagioclase phenocrysts (=20 mm) are fritted and complexly zoned; contains gray, vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite up to 30 cm in diameter; vented from hill east of Cerro del Pino; relatively fresh in west near vent but displays considerable hydrothermal alteration in east, particularly along faults and near canyon bottoms; interbedded with andesite flows (Tpa); Ar 40/39 age of sample from ridge east of vent is 9.42±0.22 Ma (Justet, 2003); exposed thickness at least 275 m north and west of Cerro del Pino. *GRI Source Map ID 7226* (OF-GM 111).

Tpbhd - Porphyritic biotite, hornblende dacite (Miocene)
Dome and flow complexes and highly faulted flows containing 10 to 15% phenocrysts of plagioclase, biotite (=3 mm), oxyhornblende (=5 mm), orthopyroxene, and clinopyroxene, in a trachytic groundmass filled with plagioclase and pyroxene microlites; groundmass also contains apatite microphenocrysts up to 0.5 mm long; plagioclase phenocrysts (=20 mm) are fritted and complexly zoned; contains gray, vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite up to 30 cm in diameter; partially obscured vent occurs beneath southwest flank of Rabbit Mountain; vent for flows east of Bearhead Ridge may occur north of Reid Canyon; fresh outcrops unusual; hydrothermal alteration consists of clay, silica, calcite, Fe-oxides, chlorite ± epidote; interbedded with andesite flows; intruded by Bearhead Rhyolite; 40Ar/39Ar age of dome and flow complex south of Rabbit Mountains is 8.66 ± 0.22 Ma; 40Ar/39Ar age of similar unit west of map area is 9.42 ± 0.22 Ma (Justet, 2003; Goff et al., 2005); age of pervasive hydrothermal alteration of this unit in upper Del Norte Canyon area is about 6.5 to 6.0 Ma (WoldeGabriel and Goff, 1989); maximum exposed thickness is at least 275 m. *GRI Source Map ID 7218* (OF-GM 85).

Tpbhd - Porphyritic biotite, hornblende dacite (Miocene)
Extensive dome and flow complex filling east-west trending paleocanyon in southern map area (Smith et al., 1970; Gardner, 1985); contains 15% phenocrysts of plagioclase, biotite (=3 mm), oxyhornblende (=5 mm), orthopyroxene, and clinopyroxene, in a trachytic groundmass filled with plagioclase and pyroxene microlites; groundmass also contains apatite microphenocrysts up to 0.5 mm long; plagioclase phenocrysts (=20 mm) are fritted and complexly zoned; contains gray, vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite up to 30 cm in diameter; vented from hill east of Cerro del

Pino; relatively fresh in west near vent but displays considerable hydrothermal alteration in east, particularly along faults and near canyon bottoms; interbedded with andesite flows (Tpa); Ar 40/39 age of sample from ridge east of vent is 9.42±0.22 Ma (Justet, 2003); exposed thickness at least 275 m north and west of Cerro del Pino. *GRI Source Map ID 6630* (OF-GM 74).

Tpmc - Paliza Canyon Formation, trachyandesite of Mesita Cocida (Miocene)

Medium to dark gray diktytaxitic lavas, poorly to moderately porphyritic with rare phenocrysts of plagioclase, pyroxene and trace amounts of olivine and hornblende. The weathered outcrop is platy in appearance. Massive, flow banded, and vesicular horizons are common. Chamberlin and McIntosh (2007) determined an age of 7.09 ± 0.21 Ma for this unit based on three samples on Mesita Cocida on the Loma Creston quadrangle. Maximum thickness exceeds 20 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpai - Paliza Canyon Formation, andesite dikes that may be the source of the trachyandesite of Mesita Cocida (Miocene)

No description given. *GRI Source Map ID 6630* (OF-GM 74).

Thb - Paliza Canyon Formation, hydrothermal breccia (Miocene)

Small areas in southeastern map area associated with volcanism of the Paliza Canyon Formation; consists of relatively circular, vertical pipes of mosaic breccia =100 m in diameter containing fragments of altered andesite and dacite in a fine-grained, silicified matrix; exact age unknown but probably =8 Ma (WoldeGabriel and Goff 1989); thickness is unknown. *GRI Source Map ID 75592* (GM 79).

Tpdt - Paliza Canyon Formation, porphyritic dacite tuff (Miocene)

Tpdt - Dacite tuff (Miocene)
White pyroclastic fall deposits containing pumice, ash, crystals, and lithic fragments commonly found in volcaniclastic deposits of Tpv; mapped only where >3 m thick and over a hundred meters in length; phenocrysts in pumice clasts generally contain plagioclase, clinopyroxene, and hypersthene, ± hornblende, ± biotite; beds often slightly silicified; beds are not laterally extensive and pinch out due to erosion; may show reverse or graded bedding; $^{40}Ar/^{39}Ar$ dates of four tuff beds in canyons east of map area range from 9.1 to 9.5 Ma (Lavine et al., 1996); maximum thickness about 10 m but most beds =1 m thick and generally too thin or discontinuous to map. *GRI Source Map ID 7225* (OF-GM 112).

Tpdt - Porphyritic dacite tuff (Miocene)
Distinctive unit of massive, lithic-rich tuff with conspicuous crystals of biotite and tiny hornblende, and crystals of plagioclase; contains lithic fragments of andesite, dacite, rhyolite, possible intrusive rocks, and sandstone in altered matrix of dense to vesicular tuff; alteration consists of silica, clay, Fe-oxides, and chlorite; exposed only in lower part of north caldera wall; K-Ar date of altered tuff is 8.20 ± 0.29 Ma (WoldeGabriel 1990); may be correlative with similar looking dacite tuff found as megabreccia block in northern part of resurgent dome (Qxpt), which has an $^{40}Ar/^{39}Ar$ age of 8.21 ± 0.08 Ma (Phillips 2004); maximum exposed thickness about 40 m. *GRI Source Map ID 75592* (GM 79).

Tpdt - Dacite tuff (Miocene)
White pyroclastic fall deposits containing pumice, ash, crystals, and lithic fragments commonly found in volcaniclastic deposits of the Paliza Canyon Formation; phenocrysts in pumice clasts generally contain plagioclase, clinopyroxene, and hypersthene, ± hornblende, ± biotite; beds often slightly silicified; beds are not laterally extensive and pinch out due to erosion; may show reverse or graded bedding; $^{40}Ar/^{39}Ar$

dates of four tuff beds within local area range from 9.1 to 9.5 Ma (Lavine et al., 1996); $^{40}Ar/^{39}Ar$ date of 1.5 m thick bed northeast of St. Peter's Dome 9.47 ± 0.06 Ma; most beds =1 m thick and generally too thin or discontinuous to map. *GRI Source Map ID 7224* (OF-GM 42).

Tpd - Paliza Canyon Formation, aphyric dacite (Miocene)

Tpd - Dacite (Miocene)
Tan to gray to black, flow banded to massive, slightly porphyritic to aphyric dacite lavas, dikes and plug; groundmass is commonly trachytic with phenocrysts of plagioclase and sparse microphenocrysts of plagioclase, clinopyroxene, hypersthene, opaque oxides ± biotite ± hornblende; pervasively altered to chlorite, silica, and clay; intrudes monzonite and andesite in Colle Canyon; ages of various units unknown; maximum exposed thickness about 30 m. *GRI Source Map ID 7225* (OF-GM 112).

Tpd - Aphyric dacite (Miocene)
Flow-banded to massive lavas containing sparse phenocrysts of plagioclase, pyroxene, hornblende, opaque oxides, and possibly potassium feldspar; plug-like body exposed north-northeast of Las Conchas is pervasively altered to chlorite, silica, and clay; intrusive breccia on the margins of the plug include small blocks and fragments of basalt and andesite in dacite host; ages of various units unknown; maximum exposed thickness about 120 m. *GRI Source Map ID 75592* (GM 79).

Tpd - Dacite (Miocene)
Light to dark gray porphyritic lavas with phenocrysts of plagioclase, hornblende, and biotite. Some lavas also contain small amounts of quartz and pyroxene. Flows are typically massive but can also exhibit flow banding and brecciated horizons. An older sequence of dacites, exposed along Forest Road 266 between Bear Springs Peak and Cerrito Yelo, is stratigraphically below most of the thick andesite package to the north. The andesite package is then capped by a younger dacitic sequence of lavas and domes. These dacitic lavas, including dome complexes at Cerro Ruiz and north of Paliza Canyon, tend to be more coarsely porphyritic, with phenocrysts of plagioclase (up to 1 cm across), pyroxene, and rare hornblende or biotite. Maximum thickness of this unit exceeds 150 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpbd - Paliza Canyon Formation, porphyritic biotite dacite (Miocene)

Tpbd - Porphyritic biotite dacite (Miocene)
Eroded domes, flows, dikes and plugs of gray to pale pink dacite having phenocrysts of plagioclase, biotite, clinopyroxene, orthopyroxene ± hornblende in a trachytic groundmass of plagioclase, pyroxene, and opaque oxides; contains complexly zoned and fritted plagioclase phenocrysts up to 15 mm in diameter; contains minor clots of plagioclase and pyroxene; many flows are extensively altered to silica, chlorite, clay, Fe-oxides ± calcite; interbedded with and intrudes andesite in most locations; interbedded with Tpv in southeast map area; dike intrudes monzonite west of Bland; intruded by Bearhead Rhyolite; ages of various units in map area unknown; $^{40}Ar/^{39}Ar$ age of flow on ridge top in west-central part of quad is 7.56 ± 0.08 Ma; K-Ar age of dome in upper Bland Canyon just south of map is 9.11 ± 0.19 Ma (Goff et al., 1990); maximum exposed thickness is 140 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkbd - Biotite dacite (Miocene)
Domes, flows, and minor intrusive rocks of gray to pink porphyritic dacite containing phenocrysts of complexly zoned plagioclase and smaller phenocrysts of plagioclase, biotite, clinopyroxene, opaque minerals, ± hornblende, ± hypersthene, ± quartz, ± potassium feldspar; flows massive to sheeted; may contain flow breccia; K-Ar age of dome in upper Cochiti Canyon 8.8 ± 0.5 Ma; K-Ar age of dome in upper Bland Canyon 9.11 ± 0.19 Ma; maximum observed thickness about 150 m. *GRI Source Map ID 7228* (SIM 3194).

Tpbd - Porphyritic biotite dacite (Miocene)
Domes and flows having phenocrysts of plagioclase, biotite, and pyroxene; contains minor clots of plagioclase and pyroxene; commonly altered to silica, chlorite, clay, Fe-oxides, and minor calcite; $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 7.38 to 7.78 Ma (Kelley et al., in press); maximum exposed thickness is 160 m. *GRI Source Map ID 75592* (GM 79).

Tpbd - Porphyritic biotite dacite (Miocene)
Eroded dome and flows of gray to pale pink dacite having =5 % phenocrysts of plagioclase, biotite, and pyroxene in a trachytic groundmass of plagioclase, pyroxene, and opaque oxides; contains complexly zoned and fritted plagioclase phenocrysts =10 mm in diameter; contains minor clots of plagioclase and pyroxene; most specimens are extensively altered to silica, chlorite, clay, Fe-oxides and minor calcite; intrudes and overlies andesite in fault zone along southeast side of map; maximum exposed thickness is 160 m. *GRI Source Map ID 7226* (OF-GM 111).

Tpbd - Biotite dacite (Miocene)
Domes, flows, and minor intrusives of gray to pink porphyritic dacite containing ~1-5% phenocrysts of plagioclase, biotite, ± clinopyroxene, ± hornblende, ± quartz. Typically massive but is flow banded or flow brecciated locally. Maximum observed thickness is about 150 m. *GRI Source Map ID 7218* (OF-GM 85).

Tpbd - Biotite dacite (Miocene)
Extensive dome and flow complex beneath the summit of St. Peter's Dome; consists of gray to pale pink porphyritic dacite with phenocrysts of complexly zoned plagioclase and smaller phenocrysts of plagioclase, biotite, clinopyroxene, and opaque minerals in devitrified groundmass; flows are massive to sheeted; flows contain flow breccia; maximum observed thickness about 150 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpbd - Biotite-bearing rhyodacite (Miocene)
Light to dark gray and pink porphyritic lavas with phenocrysts of plagioclase and biotite with minor hornblende (Guilbeau, 1982; Guilbeau and Kudo, 1985). Guilbeau (1982) referred to this unit as the rhyodacite of La Jara Canyon. *GRI Source Map ID 6630* (OF-GM 74).

Tpbb - Paliza Canyon Formation, basalt of Bodega Butte (Miocene)

Dark gray olivine basalt that is massive to vesicular and moderately porphyritic with phenocrysts of plagioclase, olivine and pyroxene. Phenocryst content is typically <10% with olivine commonly altered to reddish-brown iddingsite. Weathered surfaces on the basalt are covered with distinctive reddish speckles. Basalt breccias and vesicular horizons are common. This widespread unit in the southeast portion of the quadrangle appears to have been emplaced during one eruptive episode, although separate flows may have overlapped. An $^{40}Ar/^{39}Ar$ date for this unit from a sam ple collected at the confluence of Hondo and West Fork Canyons is 9.10 ± 0.13 Ma. Chamberlin and McIntosh (2007) determined an average age of 9.14 ± 0.12 Ma from four samples on the Loma Creston quadrangle to the south. Maximum thickness of unit exceeds 30 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpbbs - Paliza Canyon Formation, scoria facies of basalt of Bodega Butte (Miocene)

No description given. *GRI Source Map ID 6630* (OF-GM 74).

Tpbt - Paliza Canyon Formation, basalt, hydromagmatic tephra (Miocene)

No description given. *GRI Source Map ID 6630* (OF-GM 74).

Tpbi - Paliza Canyon Formation, basalt, Basaltic dikes (Miocene)

No description given. *GRI Source Map ID 6630* (OF-GM 74).

Tppa - Paliza Canyon Formation, porphyritic andesite (Miocene)

Tppa - Porphyritic andesite (Miocene)
Gray to black domes and flows of coarsely porphyritic andesite having large phenocrysts of plagioclase and abundant phenocrysts of clinopyroxene and hypersthene in a glassy almost intersertal groundmass of plagioclase, clinopyroxene, hypersthene, and opaque minerals; plagioclase may be complexly zoned; may contain plagioclase-pyroxene clots up to 10 cm in diameter; flows generally sheeted with minor flow breccia; separated from other andesites only in southeast part of map where relations are not obscured by faulting and hydrothermal alteration; flows in map area not dated; K-Ar date of flow at summit of St. Peter's Dome just east of map area is 8.69 ± 0.38 Ma (Goff et al., 1990); maximum observed thickness is about 150 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkpa - Porphyritic andesite (Miocene)
Gray to black domes and flows of coarse porphyritic andesite having large phenocrysts of plagioclase and abundant phenocrysts of clinopyroxene and hypersthene; flows may be sheeted or contain flow breccia; K-Ar age of flow at summit of St. Peters Dome 8.69 ± 0.38 Ma; K-Ar age of dome west of Rancho Canada 9.33 ± 0.19 Ma; maximum observed thickness about 150 m. *GRI Source Map ID 7228* (SIM 3194).

Tppa - Porphyritic andesite (Miocene)
Massive to sheeted flows of coarsely porphyritic lava having large phenocrysts of plagioclase and abundant phenocrysts of clinopyroxene and hypersthene; may contain plagioclase-pyroxene clots; flows in map area not dated; K-Ar age of similar flow at summit of St. Peter's Dome just east of map area is 8.69 ± 0.38 Ma (Goff et al. 1990); maximum observed thickness is about 150 m. *GRI Source Map ID 75592* (GM 79).

Tppa - Porphyritic andesite (Miocene)
Domes and flows of coarse, gray to black porphyritic andesite having large phenocrysts of plagioclase and abundant phenocrysts of clinopyroxene and hypersthene in a glassy almost intersertal groundmass of plagioclase, clinopyroxene, hypersthene, and opaque minerals. Plagioclase may be complexly zoned, and may contain clots up to 20 cm in diameter. Flows may be sheeted or contain flow breccia. K-Ar age west of Rancho Canada 9.33 ± 0.19 Ma (Goff et al., 1990). Maximum observed thickness about 150 m. *GRI Source Map ID 7218* (OF-GM 85).

Tppa - Porphyritic andesite (Miocene)
Gray to black domes and flows of coarsely porphyritic andesite having large phenocrysts of plagioclase and abundant phenocrysts of clinopyroxene and hypersthene in a glassy, almost intersertal, groundmass of plagioclase, clinopyroxene, hypersthene, and opaque minerals; plagioclase may be complexly zoned; may contain plagioclase-pyroxene clots up to 10 cm in diameter; flows generally sheeted with minor flow breccia; K-Ar date of flow at summit of St. Peter's Dome 8.69 ± 0.38 Ma (Goff et al., 1990); maximum observed thickness about 150 m. *GRI Source Map ID 7224* (OF-GM 42).

Tphd - Paliza Canyon Formation, porphyritic hornblende dacite (Miocene)

Tkhd - Hornblende dacite (Miocene)
Domes, flows, and minor intrusive rocks of gray to pink porphyritic dacite containing phenocrysts of complexly zoned plagioclase and smaller phenocrysts of plagioclase, hornblende, clinopyroxene, opaque minerals, ± biotite, ± hypersthene, ± apatite, ± potassium feldspar; flows massive to sheeted; may contain flow breccia. K-Ar age of dome at head of Sanchez Canyon 9.5 ± 2.5 Ma; K-Ar age of dome on southeast slope of Boundary Peak 9.48 ± 0.44 Ma; maximum observed thickness about 60 m. *GRI Source Map ID 7228* (SIM 3194).

Tphd - Porphyritic hornblende dacite (Miocene)
Eroded flows capping the summits of Las Conchas, Los Griegos, and other hills south of the caldera; phenocrysts consist of plagioclase, hornblende, orthopyroxene, and clinopyroxene; flows may contain plagioclasepyroxene clots; some units pervasively altered to silica, Fe-oxides, calcite, and chlorite; $^{40}Ar/^{39}Ar$ age on Los Griegos is 8.53 ± 0.63 Ma (Kelley et al., in press); maximum exposed thickness is 75 m. *GRI Source Map ID 75592* (GM 79).

Tphd - Hornblende dacite (Miocene)
Domes, flows, and minor intrusives of gray to pink porphyritic dacite containing ~1-5% phenocrysts of plagioclase, hornblende, minor clinopyroxene, ± biotite. May contain clots of plagioclase and mafic minerals. Flows massive to banded, may contain flow breccia. Outcrop in NW corner of quadrangle is coarsely porphyritic with plagioclase and hornblende phenocrysts up to 1 cm. Maximum observed thickness about 60 m. *GRI Source Map ID 7218* (OF-GM 85).

Tpha - Paliza Canyon Formation, hornblende andesite (Miocene)

Tpha - Hornblende andesite (Miocene)
Gray to black flows, dome, and plug of glassy to devitrified andesite having small phenocrysts of plagioclase, clinopyroxene, oxidized to fresh hornblende ± hypersthene ± rare biotite in a trachytic to nearly intersertal groundmass of plagioclase, clinopyroxene, opaque minerals ± hypersthene ± hornblende; plagioclase may be complexly zoned; may contain plagioclase-pyroxene or plagioclase-hornblende clots; may display flow banding or contain flow breccia; ages of various exposures unknown; maximum exposed thickness about 45 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkha - Hornblende andesite (Miocene)
Black to gray to pink domes and flows of glassy to devitrified andesite having small phenocrysts of plagioclase, clinopyroxene, oxidized hornblende ± hypersthene ± rare biotite; may display flow banding or contain flow breccia; ages of various flows unknown; maximum observed thickness about 45 m. *GRI Source Map ID 7228* (SIM 3194).

Tpha - Hornblende andesite (Miocene)
Plug of flow-banded, devitrified lava on southeast caldera margin having small phenocrysts of plagioclase, hornblende, clinopyroxene, and hypersthene; age of unit unknown; maximum exposed thickness about 45 m. *GRI Source Map ID 75592* (GM 79).

Tm - Paliza Canyon Formation, Monzonite dikes and stocks (Miocene)

Tm - Monzonite intrusive bodies (Miocene)
Dikes, sills, pods, plugs and stocks of crystalline rocks collectively called monzonite (after Bundy, 1958); textures range from coarse-grained, hypidiomorphic granular and seriate to fine-grained, trachytic and porphyritic. Stein (1983) describes the full range of textures, mineralogy and chemical compositions in these intrusives, which range from monzonite to quartz monzonite; apparently a compound stock in

the Bland area; primary minerals consist of plagioclase, clinopyroxene, orthopyroxene, potassium feldspar and quartz ± biotite ± hornblende. Alteration is moderate to intense, argillic to propylitic; replacement minerals consist mainly of clays, Fe, Mn-oxides, silica, calcite, illite, chlorite, epidote and pyrite; rank of alteration generally increases toward bottoms of canyons; locally contains cavities of quartz-chlorite-epidote-calcite; larger stock west of Washington Hill contains plexus of unmapped dikes with pronounced north-northwest trend; other stocks and plugs display central core of monzonite from which radiate monzonite dikes; width of single dikes shown on map are usually exaggerated and may consist of up to 20 thin, semi-parallel dikes; vent areas shown on map represent crystallized roots of andesitic to dacitic volcanoes of the Paliza Canyon Formation; monzonite intrudes basalt, andesite, volcaniclastic sediments (Tpv) and Santa Fe Group; overlain and intruded by andesite, dacite and Bearhead Rhyolite; K-Ar date on relatively unaltered sample from unspecified location is 11.3 ± 0.3 Ma (Stein, 1983); altered monzonite from main stock has $^{40}Ar/^{39}Ar$ ages of 7.8 to 7.4 Ma; maximum exposed thickness east of Colle Canyon is about 275 m. *GRI Source Map ID 7225* (OF-GM 112).

Tm - Monzonite dikes and stocks (Miocene)
Characterized in detail by Stein (1983). Contains phenocrysts and locally glomerocrysts of plagioclase and augite set in a fine-grained phaneritic to aphanitic groundmass of plagioclase, orthoclase, quartz, and augite. Fine-grained or aphanitic locally. Light to very dark gray to dark green to black, pervasively hydrothermally altered. Present along Colle Canyon in footwall of major NE-striking fault. Intruded by Tbi. Dikes range between 1 cm to 30 m wide, trend northerly, and are vertical. *GRI Source Map ID 7218* (OF-GM 85).

Tct - Canovas Canyon Rhyolite lavas (Miocene)

Mostly beige to pinkish-gray, flow-banded, phenocryst-poor lavas. Dark grey to green obsidian facies common in more voluminous flows. Phenocrysts are typically small (< 2 mm) and include biotite, sanidine, and rare quartz. West of the Cocida fault zone pyroclastic deposits are intercalated with sandstones, tuff breccia, and tephra deposits. The largest contiguous flow occurs east of Bear Springs Peak and covers an area of > 6 km2. Although the thickness of this unit is unknown (the base of the flow is not exposed), the flow is widespread and appears to have a relatively low-aspect ratio more typical of lavas with a lower silica content. A similarly widespread pyroclastic flow overlies the lava and in several locations the two units appear to be intimately associated with one another, suggesting a continuum in the eruption process. Other rhyolite lavas of this unit are of limited lateral distribution (< 1 km2) and exhibit a more typical high-aspect ratio morphology. Most of the Canovas Canyon rhyolites were erupted along N-S-trending faults active during the Mid-Miocene. $^{40}Ar/^{39}Ar$ dates for biotite from flows at 0361786 3948981 and 357602 3946081 are 8.81 ± 0.16 Ma and 9.75 ± 0.08 Ma, respectively. Justet (2003) determined $^{40}Ar/^{39}Ar$ dates of 9.30 ± 0.05 Ma for Borrego Dome and 8.00 ± 0.60 and 8.65 ± 0.35 Ma for flows from the Bear Springs Peak center. Maximum thickness exceeds 150 meters. *Note: Lithologic relationship with Tcct unknown. GRI Source Map ID 6630* (OF-GM 74).

Tcct - Canovas Canyon Rhyolite (Miocene)

Tkct - Canovas Canyon Rhyolite (Miocene)
White to pink ash-fall and ash-flow tuffs best preserved in laharic deposits of the Cochiti Formation; "pink tuff" apparently underlies all other Keres Group volcanic rocks and overlies Santa Fe Group on south and east flanks of St. Peters Dome; estimated age range of unit 9.0–13.0 Ma; maximum observed thickness about 20 m. *GRI Source Map ID 7228* (SIM 3194).

Tcc - Canovas Canyon Rhyolite (Miocene)
Hydrothermally altered lava in bottom of Medio Dia Canyon at Evans-Griffin Place; unit contains quartz, feldspar, biotite, and possibly hornblende altered to silica, clay, Fe-oxide, illite, and chlorite; some specimens contain calcite; underlies basalt; bottom of unit not exposed; age unknown but probably

around 10 Ma; maximum exposed thickness about 10 m. *GRI Source Map ID 75592* (GM 79).

Tcct - Canovas Canyon Rhyolite tuff (Miocene)
Poorly exposed unit in bottom of Peralta Canyon at southern edge of map; consists of bedded aphyric pumice and lithic fragments of sandstone and mafic volcanics in altered matrix of clay-rich rhyolitic ash; underlies Tpa; relation to Tpb unknown; maximum exposed thickness roughly 35 m. *GRI Source Map ID 7226* (OF-GM 111).

Tcct - Canovas Canyon Rhyolite tuff (Miocene)
White to pink ash-fall and ash-flow tuffs. Consists of at least four mappable units. Lowermost unit consists of pink lithic-rich ash-fall tuff containing abundant lithic fragments of pink flow-banded rhyolite. Other units consist of thin beds of white, fine-grained ash and pumice. Maximum observed thickness about 20 m. *GRI Source Map ID 7218* (OF-GM 85).

Tcct - Canovas Canyon Rhyolite tuff (Miocene)
White to pink pyroclastic fall and pyroclastic flow deposits of the Canovas Canyon Rhyolite (Bailey et al., 1969; Gardner et al., 1986); consists of several distinct deposits; lowermost unit exposed on east flank of St. Peter's Dome consists of pink, lithic-rich tuff containing abundant fragments of flow banded rhyolite (informally named the "pink tuff"); at other localities unit may contain white fine- to course-grained fall deposits; pumice and rhyolite clasts contain sparse phenocrysts of quartz, potassium feldspar, and biotite; unit is interbedded with older volcaniclastic deposits of the Paliza Canyon Formation; "pink tuff" underlies all other Keres Group rocks and overlies Santa Fe Group on the east side of St. Peter's Dome; estimated age range for various tuff deposits is about 10 to 13 Ma (Goff et al., 1990); maximum observed thickness about 20 m. *GRI Source Map ID 7224* (OF-GM 42).

Tcct - Canovas Canyon rhyolite, associated pyroclastic and alluvial deposits (Miocene)
Mostly beige to pinkish-gray, flow-banded, phenocryst-poor lavas. Dark grey to green obsidian facies common in more voluminous flows. Phenocrysts are typically small (< 2 mm) and include biotite, sanidine, and rare quartz. West of the Cocida fault zone pyroclastic deposits are intercalated with sandstones, tuff breccia, and tephra deposits. The largest contiguous flow occurs east of Bear Springs Peak and covers an area of > 6 km2. Although the thickness of this unit is unknown (the base of the flow is not exposed), the flow is widespread and appears to have a relatively low-aspect ratio more typical of lavas with a lower silica content. A similarly widespread pyroclastic flow overlies the lava and in several locations the two units appear to be intimately associated with one another, suggesting a continuum in the eruption process. Other rhyolite lavas of this unit are of limited lateral distribution (< 1 km2) and exhibit a more typical high-aspect ratio morphology. Most of the Canovas Canyon rhyolites were erupted along N-S-trending faults active during the Mid-Miocene. $^{40}Ar/^{39}Ar$ dates for biotite from flows at 0361786 3948981 and 357602 3946081 are 8.81 ± 0.16 Ma and 9.75 ± 0.08 Ma, respectively. Justet (2003) determined $^{40}Ar/^{39}Ar$ dates of 9.30 ± 0.05 Ma for Borrego Dome and 8.00 ± 0.60 and 8.65 ± 0.35 Ma for flows from the Bear Springs Peak center. Maximum thickness exceeds 150 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tcc - Canovas Canyon Rhyolite, domes, flows, and intrusions (Miocene)

Tcc - Canovas Canyon rhyolite (Miocene)
Domes, flows, and intrusions. White to gray to pink, flowbanded devitrified rhyolite and rhyodacite. Contains phenocrysts of quartz, plagioclase, biotite, ± sanidine, ± hornblende. May contain flow breccia, perlite, and rare obsidian at margins of intrusions. Tcc underlies or intrudes intermediate-composition rocks of lower Keres Group. K-Ar ages of four domes and flows range from 9.24 ± 1.50 Ma to 12.4 ± 2.0 Ma (Goff et al., 1990). Maximum observed thickness about 110 m. *GRI Source Map ID 7218* (OF-GM 85).

Tcc - Canovas Canyon rhyolite lavas (Miocene)
Mostly beige to pinkish-gray, flow-banded, phenocryst-poor lavas. Dark grey to green obsidian facies common in more voluminous flows. Phenocrysts are typically small (< 2 mm) and include biotite, sanidine, and rare quartz. West of the Cocida fault zone pyroclastic deposits are intercalated with sandstones, tuff breccia, and tephra deposits. The largest contiguous flow occurs east of Bear Springs Peak and covers an area of > 6 km2. Although the thickness of this unit is unknown (the base of the flow is not exposed), the flow is widespread and appears to have a relatively low-aspect ratio more typical of lavas with a lower silica content. A similarly widespread pyroclastic flow overlies the lava and in several locations the two units appear to be intimately associated with one another, suggesting a continuum in the eruption process. Other rhyolite lavas of this unit are of limited lateral distribution (<1 km2) and exhibit a more typical high-aspect ratio morphology. Most of the Canovas Canyon rhyolites were erupted along N-S-trending faults active during the Mid-Miocene. $^{40}Ar/^{39}Ar$ dates for biotite from flows at 0361786 3948981 and 357602 3946081 are 8.81 ± 0.16 Ma and 9.75 ± 0.08 Ma, respectively. Justet (2003) determined $^{40}Ar/^{39}Ar$ dates of 9.30 ± 0.05 Ma for Borrego Dome and 8.00 ± 0.60 and 8.65 ± 0.35 Ma for flows from the Bear Springs Peak center. Maximum thickness exceeds 150 meters. *GRI Source Map ID 6630* (OF-GM 74).

Tpoa - Olivine andesite (Miocene)

Tpoa - Olivine andesite (Miocene)
Black to gray dome and flow complex with minor red cinder deposits occurring in southeast map area; consists of slightly porphyritic andesite with phenocrysts of plagioclase, clinopyroxene, and olivine ± hypersthene in a glassy to almost intersertal groundmass; olivine may show both high- and low-temperature iddingsite; may contain sparse plagioclase-pyroxene clots; may contain apatite microphenocrysts; flows massive to sheeted, commonly with vesicular flow tops; apparently intruded by Tppa on east and overlain by Tpha on west; age of unit unknown; maximum observed thickness about 70 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkoa - Olivine andesite (Miocene)
Black to gray domes and flows and minor red cinder deposits of plagioclase, clinopyroxene, hypersthene and iddingsitized olivine; flows massive with vesicular flow tops; flows rarely sheeted; ages of various flows unknown; maximum observed thickness about 210 m. *GRI Source Map ID 7228* (SIM 3194).

Tpoa - Olivine andesite (Miocene)
Dome and flow complex exposed in southeast map area; consists of massive to sheeted, slightly porphyritic lava with phenocrysts of plagioclase, clinopyroxene, olivine ± hypersthene; contains sparse plagioclase-pyroxene clots; age of unit unknown; maximum observed thickness about 70 m. *GRI Source Map ID 75592* (GM 79).

Tpoa - Olivine andesite (Miocene)
Domes and flows of black to gray andesite and minor red cinder deposits. Contains plagioclase, clinopyroxene, hypersthene and iddingsitized olivine in itersertal to glassy groundmass. May contain sparse plagioclase-pyroxene clots. May contain apatite microphenocrysts. Flows massive with vesicular flow tops. Flows rarely sheeted. *GRI Source Map ID 7218* (OF-GM 85).

Tpoa - Olivine andesite (Miocene)
Black to gray domes, flows, and minor red cinder deposits of slightly porphyritic andesite containing phenocrysts of plagioclase, clinopyroxene, and olivine ± hypersthene in a glassy to almost intersertal groundmass; olivine may show both high- and low-temperature iddingsite; may contain sparse plagioclase-pyroxene clots; may contain apatite microphenocrysts; flows massive to sheeted, commonly with vesicular flow tops; ages of various flows unknown; maximum observed thickness about 70 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpcm - Basalt of Chamisa Mesa (Miocene)

Tpca - Clot-rich andesite (Miocene)
Extensive dome and flow complex beneath the summit of St. Peter's Dome occurring in extreme southeast corner of map; consists of gray to black porphyritic andesite with abundant distinctive plagioclase-pyroxene clots 2 mm in diameter and phenocrysts of plagioclase, clinopyroxene, and hypersthene in a glassy almost intersertal groundmass; microphenocrysts consist of plagioclase, clinopyroxene, hypersthene, and opaque minerals; flows massive, rarely brecciated or sheeted; unit not dated; maximum observed thickness is about 50 m. *GRI Source Map ID 7225* (OF-GM 112).

Tkca - Clotted andesite (Miocene)
Gray to black flows of porphyritic andesite having abundant distinctive plagioclase-pyroxene clots 2 mm in diameter and phenocrysts of plagioclase, clinopyroxene, and hypersthene; flows massive, rarely sheeted or brecciated; ages of flows unknown; maximum observed thickness about 50 m. *GRI Source Map ID 7228* (SIM 3194).

Tpca - Clot-rich andesite (Miocene)
Extensive dome and flow complex beneath the summit of St. Peter's Dome; consists of gray to black porphyritic andesite with abundant distinctive plagioclase-pyroxene clots 2 mm in diameter and phenocrysts of plagioclase, clinopyroxene, and hypersthene in a glassy, almost intersertal, groundmass; microphenocrysts consist of plagioclase, clinopyroxene, hypersthene, and opaque minerals; flows massive, rarely brecciated or sheeted; maximum observed thickness about 50 m. *GRI Source Map ID 7224* (OF-GM 42).

Tpcm - Source Name (Miocene)
Dark gray to black, aphyric to phenochyst poor basalt with rare phenocrysts of olivine and plagioclase. Chamberlin and McIntosh (2007) determined a $^{40}Ar/^{39}Ar$ age of 9.9 ± 0.9 Ma for this flow based on two samples from the Loma Creston quadrangle to the south. Justet (2003) calculated a $^{40}Ar/^{39}Ar$ age of 10.96 ± 0.29 for the flow exposed in Borrego Canyon in the southwestern corner of the quadrangle. *GRI Source Map ID 6630* (OF-GM 74).

Tbm - Bland monzonite (Miocene)

Dikes and plug of crystalline rocks in southeastern map area south of Evans-Griffin Place (see Bundy 1958; Stein 1983); textures range from coarse grained, hypidiomorphic granular, and seriate to fine grained, trachytic, and porphyritic; primary minerals consist of plagioclase, clinopyroxene, orthopyroxene, potassium feldspar, and sparse quartz ± biotite ± hornblende. Alteration is moderate to intense, argillic to propylitic; replacement minerals consist mainly of clays, Fe- and Mn-oxides, silica, calcite, illite, chlorite, epidote, and pyrite; widths of single dikes shown on map are usually exaggerated; vent area shown on map represents crystallized core of Paliza Canyon Formation volcano; crosscutting relations indicate age 9.5 Ma; K-Ar age on relatively unaltered sample from unspecified location in the Bland district southeast of map is 11.3 ± 0.3 Ma (Stein 1983); altered monzonite from stock in Bland district has $^{40}Ar/^{39}Ar$ ages ranging from 6.5 to 78 Ma (Kelley et al., in press); maximum exposed thickness is about 275 m. *Note: Symbol in source data is Tm. GRI Source Map ID 75592* (GM 79).

Tlb - Polvadera Group volcanic rocks (Miocene)

Dark gray to black basalt with olivine and plagioclase phenocrysts correlated with the Lobato Formation. $^{40}Ar/^{39}Ar$ ages of 10.2-13.1 Ma were determined for basalt flows in the Lobato Formation just north of the quadrangle boundary (WoldeGabriel et al., 2006). *GRI Source Map ID 6633* (OF-GM 55).

Ta - Abiquiu Formation (Miocene to Oligocene)

Ta - Abiquiu Formation (Miocene to Oligocene)
White to tan, medium-grained, medium-bedded, volcaniclastic sandstone that is alternately well cemented and poorly cemented. Contains white, fine-grained ash beds that are <0.3 m thick and rare thin red mudstone intervals; maximum thickness 40 m. *GRI Source Map ID 75592* (GM 79).

Tab - Abiquiu Formation (Miocene to Oligocene?)
White to buff well-bedded sandstone and siltstone; contains grains of rounded to subangular quartz, plagioclase, potassium feldspar, quartzite, and crystalline rocks; contains rare grains of diopside and possible tremolite; cement is commonly opaline; thus beds are sometimes very indurated; calcite and limonite cement less common; well-exposed in San Juan Canyon where it underlies basaltic rocks (Tpb); maximum observed thickness is 120 m; $Ar^{40/39}$ age on ash bed in upper Abiquiu Formation to southwest is 20.6 ± 0.1 Ma (Osburn et al., 2002). *GRI Source Map ID 7226* (OF-GM 111).

Tgs - Galisteo Formation (Eocene)

Tgs - Galisteo Formation (Eocene)
Tan and pink to brownish red beds of well-indurated sandstone, siltstone, arkose, and conglomerate; conglomerate beds locally contain limestone, chert, and granitic fragments from pebble to boulder size eroded from Paleozoic and Precambrian rocks. Exposed on rotated fault block with beds dipping steeply west in northwest part of map area. Unconformably underlies Santa Fe Group; base of unit not exposed; maximum observed thickness about 200 m. *GRI Source Map ID 7228* (SIM 3194).

Tgs - Galisteo Formation (Eocene)
Orange to tan to brick red beds of well-indurated sandstone, siltstone, arkose, and conglomerate; conglomerate beds may preferentially contain limestone, chert, and granitoid fragments from pebble to boulder size from eroded Paleozoic and Precambrian sources; unit exposed on rotated fault block with beds dipping steeply to west along east flank of St. Peter's Dome; unconformably underlies the Santa Fe Group; bottom of unit not exposed; maximum observed thickness about 200 m. *GRI Source Map ID 7224* (OF-GM 42).

TRcu - Upper Chinle Group, undivided (Triassic)

TRcu - Upper Chinle Group, undivided (Triassic)
Includes the Salitral Shale, Poleo Sandstone, and Petrified Forest Formation. Primarily brick-red to maroon, poorly exposed mudstone; thin (<5 m) bed of black conglomerate with well-rounded chert and quartz pebbles belonging to the Poleo Sandstone is exposed south of East Fork Jemez River; estimated thickness 30 m. *GRI Source Map ID 75592* (GM 79).

TRc - Undivided upper part of Chinle Group (Triassic)
Poorly exposed red siltstone in the northwestern part of the quadrangle. *GRI Source Map ID 6630* (OF-GM 74).

TRcs - Shinarump Formation (Triassic)

White to yellowish-brown, medium- to coarse-grained quartzose sandstone and conglomerate; conglomerate contains well-rounded chert, quartz pebbles, and petrified wood; sandstone typically cross-stratified, commonly in trough geometries; maximum thickness 20 m. *GRI Source Map ID 75592* (GM 79).

TRm - Moenkopi Formation (Triassic)

Reddish-brown, micaceous shale, silty shale, and crossbedded arkosic sandstone; unit is shale-rich at the base and sandy at the top; approximately 20 m thick. *GRI Source Map ID 75592* (GM 79).

Pg - Glorieta Sandstone (Permian)

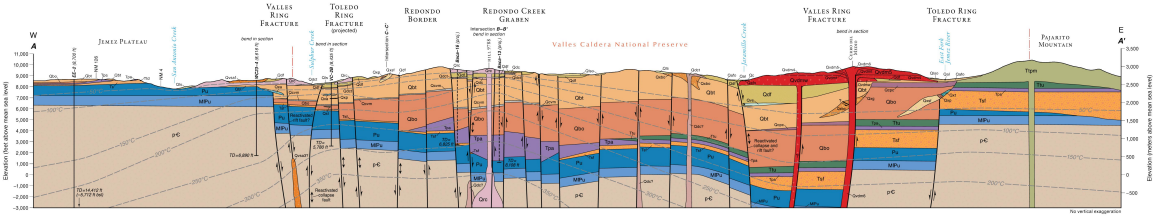
White to gray, massive to planar-bedded to cross-stratified quartz arenite typically well sorted contact with the underlying Yeso Group is gradational; approximately 20 m thick. *GRI Source Map ID 75592* (GM 79).

Py - Yeso Group (Permian)

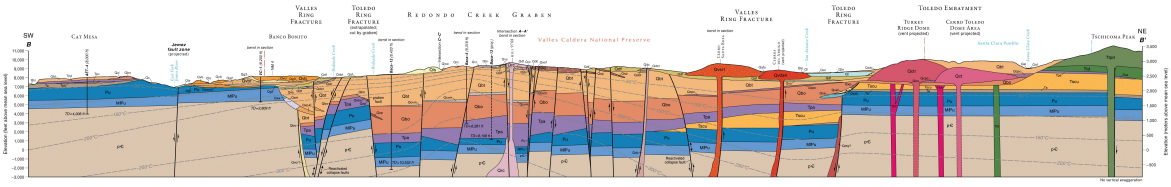
Red-orange to red, fine- to medium-grained quartzose sandstone; includes two formations in this region: the lower De Chelly (formerly Mesita Blanca) and the upper San Ysidro. The De Chelly Formation is well-sorted, eolian sandstone with meterscale crossbeds. The San Ysidro Formation is medium-bedded, tabular sandstone that is orange red near the base and red near the top. A discontinuous 1-2-m-thick limestone bed is present near the top of the unit; maximum thickness 170 m. *GRI Source Map ID 75592* (GM 79).

Geologic Cross Sections

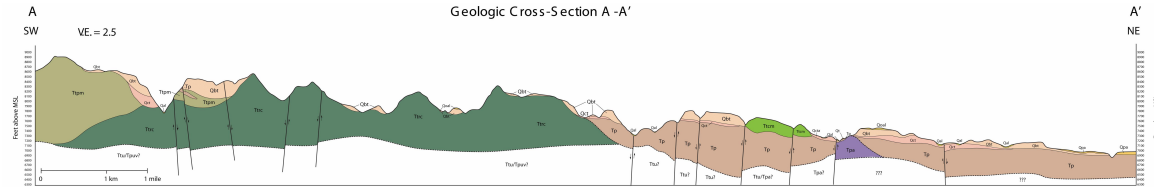
The geologic cross sections present in the GRI digital geologic-GIS data produced for Bandelier National Monument, New Mexico (BAND) are presented below. Note that some cross section abbreviations (e.g., A - A') may have been changed from their source map abbreviation in the GRI GIS data so that each GRI cross section abbreviation is unique. Colors of geologic units in the GRI GIS data also differ from respective units in these cross sections.



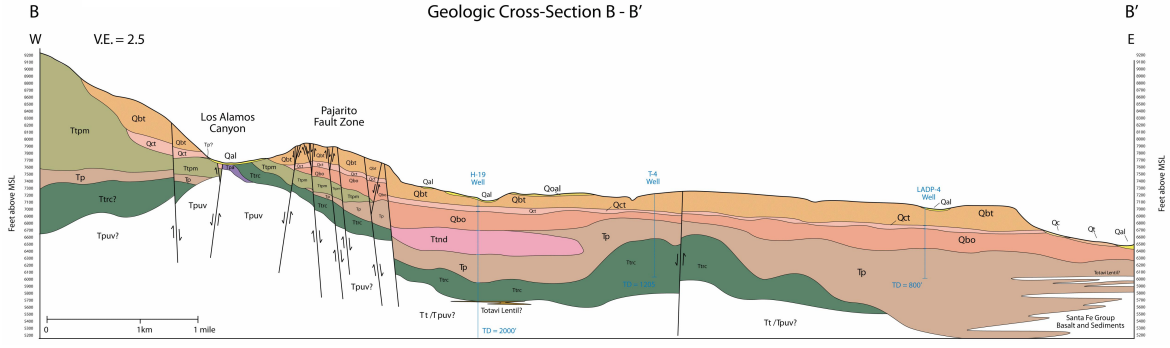
From Valles Caldera. Displayed as A-A' in GRI digital geologic-GIS data. *Extracted from:* (GM 79).



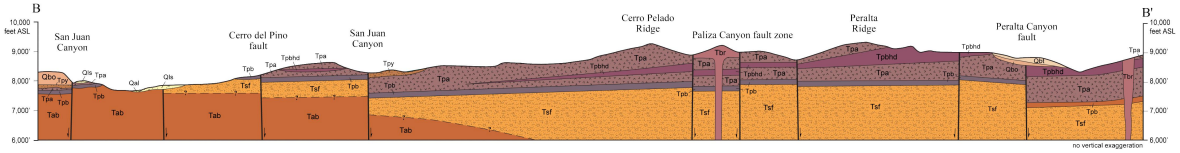
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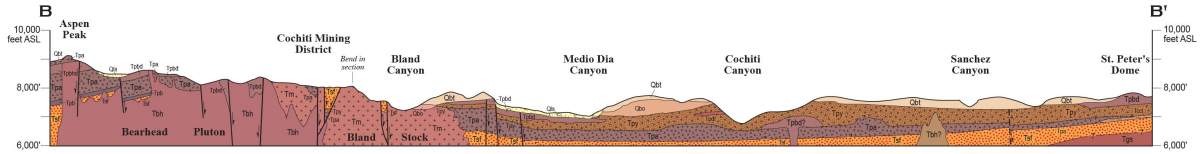
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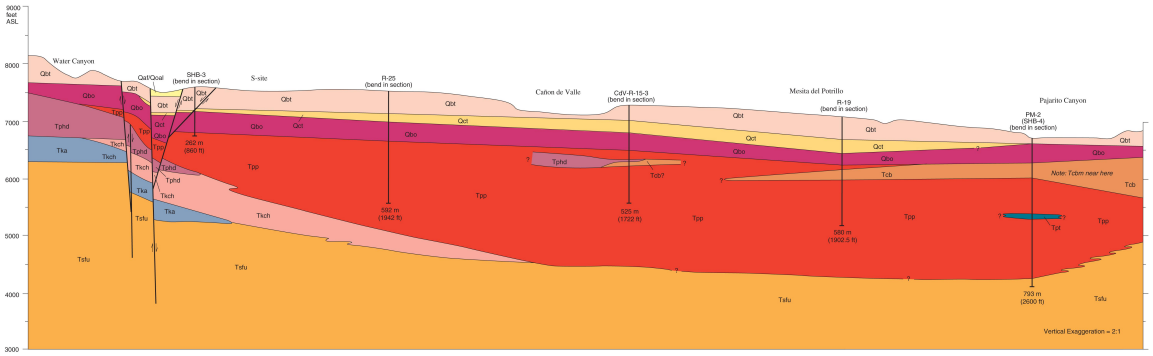
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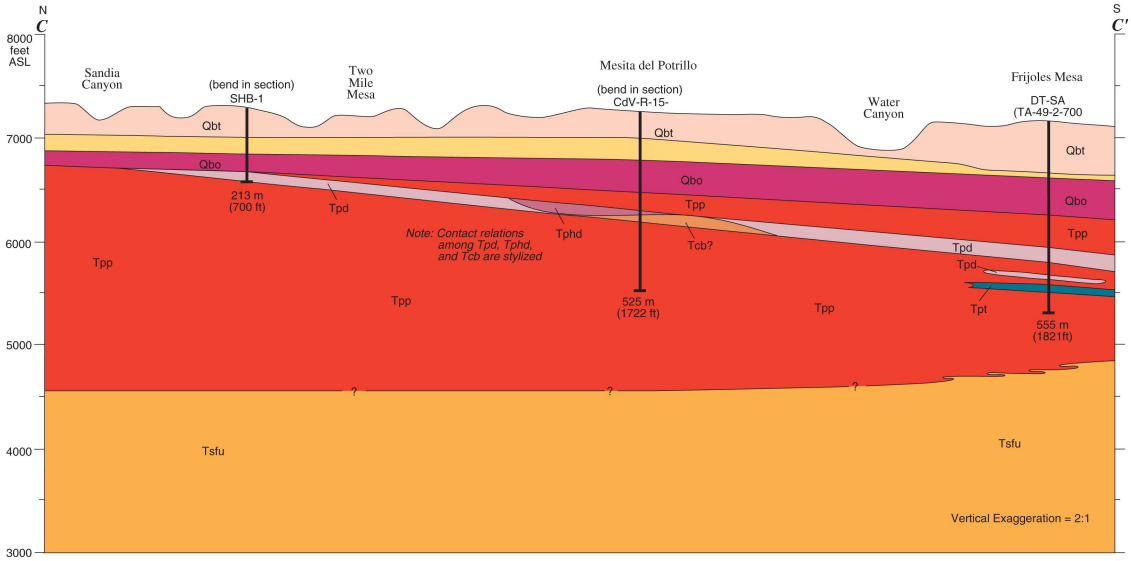
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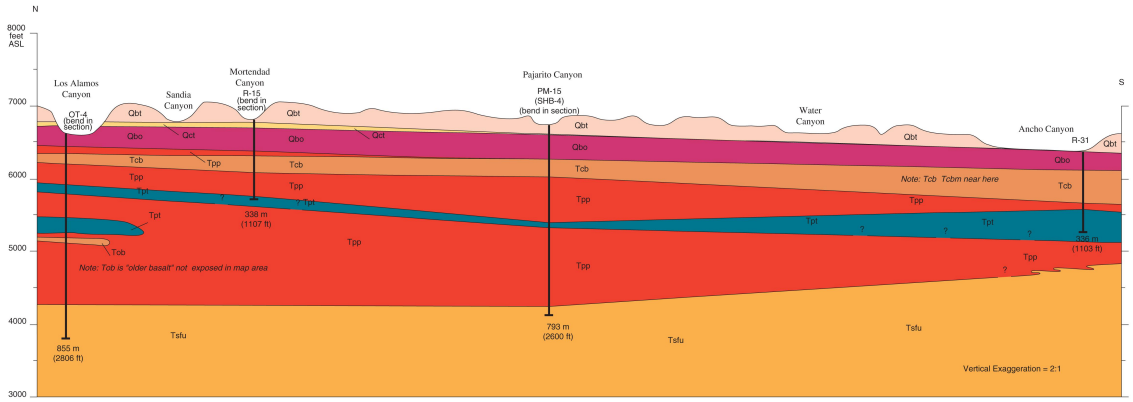
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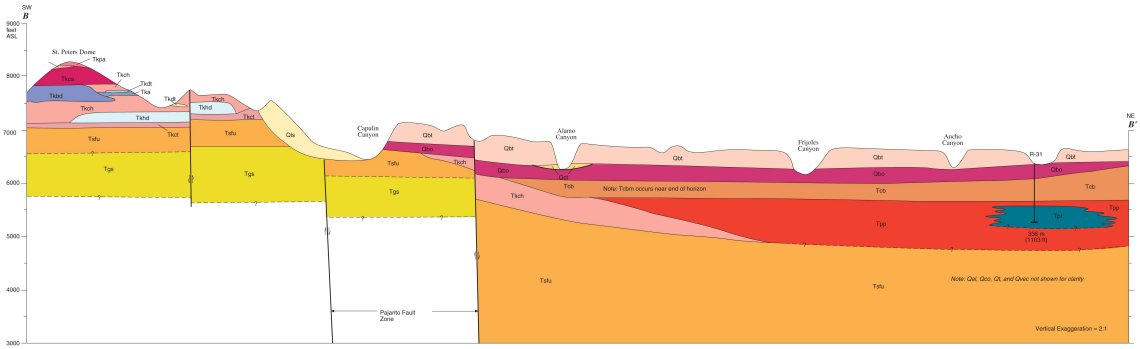
From Frijoles Quad. Displayed as G-G' in GRI digital geologic-GIS data. *Extracted from:* (OF-GM 42).



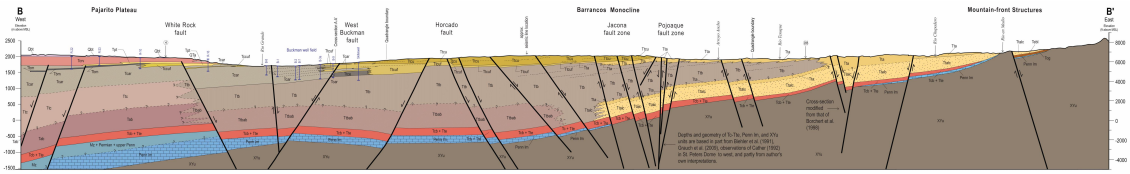
From Frijoles Quad. Displayed as H-H' in GRI digital geologic-GIS data. *Extracted from:* (OF-GM 42).



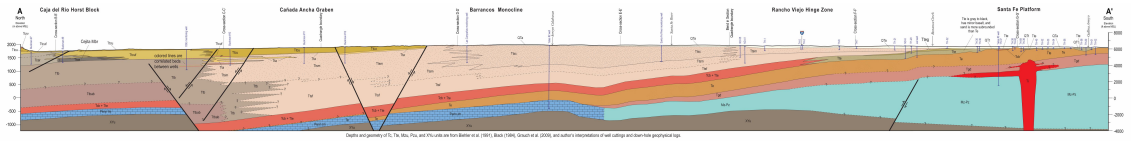
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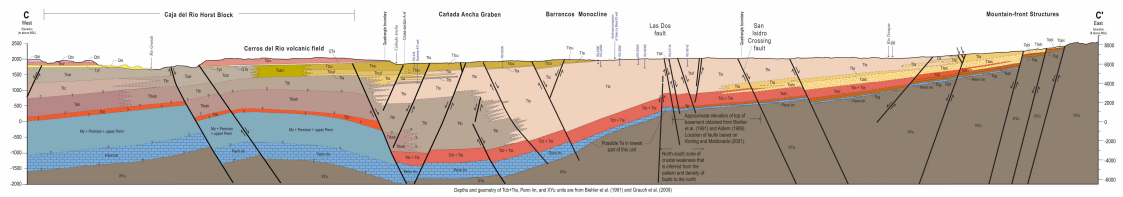
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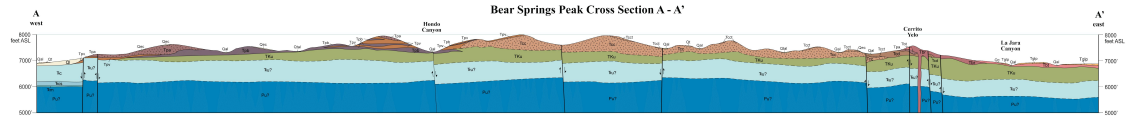
From Southern Espanola Basin. Displayed as K-K' in GRI digital geologic-GIS data. *Extracted from:* (OFR 531).



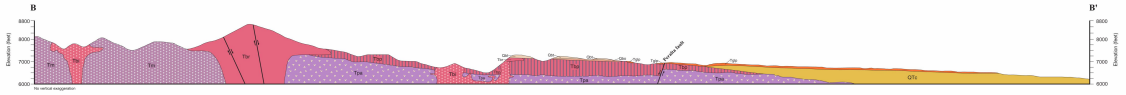
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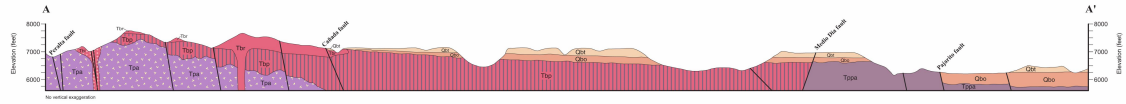
From Southern Espanola Basin. Displayed as M-M' in GRI digital geologic-GIS data. *Extracted from:* (OFR 531).



From Bear Springs Peak Quad. Displayed as N-N' in GRI digital geologic-GIS data. *Extracted from:* (OF-GM 74).



From Canada Quad. Displayed as O-O' in GRI digital geologic-GIS data. *Extracted from:* (OF-GM 85).



From Canada Quad. Displayed as P-P' in GRI digital geologic-GIS data. *Extracted from:* (OF-GM 85).

GRI Source Map Citations

The GRI digital geologic-GIS map for Bandelier National Monument, New Mexico (BAND) was compiled from the following sources (maps listed by publication date):

Goff, F., Reneau, S.L., Lynch, S., Goff, C.J., Gardner, J.N., Drakos, P., and Katzman, D., 2012, Preliminary Geologic Map of the Bland Quadrangle, Los Alamos and Sandoval Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 112, 1:24000 scale (*GRI Source Map ID 7225*)

Dethier, D.P., Thompson, R.A., Hudson, M.R., Minor, S.A., and Sawyer, D.A., 2011, Geologic Map of the Cochiti Dam Quadrangle, Sandoval County, New Mexico, U.S. Geological Survey, Scientific Investigations Map SIM-3194, 1:24,000 scale. (*GRI Source Map ID 7228*)

Goff, Fraser, Gardner, J.N., Reneau, S.L., Kelley, S.A., Kempter, K.A., and Lawrence, J.R., 2011, Geologic Map of the Valles Caldera, Jemez Mountains, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Geologic Map 79, 1:50000 scale. (*GRI Source Map ID 75592*)

Kempter, K.A., Kelley, S., Gardner, J.N., Reneau, S.L., Broxton, D.E., Goff, F., Levine, A. and Lewis, C., 2011, Geologic Map of the Guaje Mountain Quadrangle, Los Alamos and Sandoval Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 55, 1:24000 scale (*GRI Source Map ID 6633*)

Thompson, R. A., Hudson, M.R., Shroba, R.R., Minor, S.A., and Sawyer, D.A., 2011, Geologic Map of the Montoso Peak Quadrangle, Santa Fe and Sandoval Counties, New Mexico, U.S. Geological Survey, Scientific Investigations Map SIM-3179, 1:24000 scale. (*GRI Source Map ID 75593*)

Koning, D.J. and Read, A.S., 2010, Geologic Map of the Southern Espanola Basin, Santa Fe County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Report 531, 1:50000 scale. (*GRI Source Map ID 75477*)

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Lynch, S.D., Smith, G.A., and Kuhle, A.J., 2008, Preliminary Geologic Map of the Canada Quadrangle, New Mexico, U.S. Geological Survey, Open-File Geologic Map OF-GM 85, 1:24000 scale (*GRI Source Map ID 7218*)

Goff, F., Gardner, J.N., and Reneau, S.L., 2007, Preliminary Geologic Map of the Frijoles Quadrangle, Los Alamos and Santa Fe Counties, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Open-File Geologic Map OF-GM 42, 1:24000 scale (*GRI Source Map ID 7224*)

Kempter, K.A., Osburn, R.O., Kelley, S., Rampey, M., Ferguson, C. and Gardner, J., 2007, Preliminary Geologic Map of the Bear Springs Peak Quadrangle, Sandoval County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 74, 1:24000 scale (*GRI Source Map ID 6630*)

Dethier, D.P., 2003, Geologic Map of the Puye Quadrangle, Los Alamos, Rio Arriba, Sandoval, and Santa Fe Counties, New Mexico, U.S. Geological Survey, Miscellaneous Field Studies Map MF-2419, 1:24000 scale (*GRI Source Map ID 6547*)

Additional information pertaining to each source map is also presented in the Source Map Information

(BANDMAP) table included with the GRI geology-GIS data.

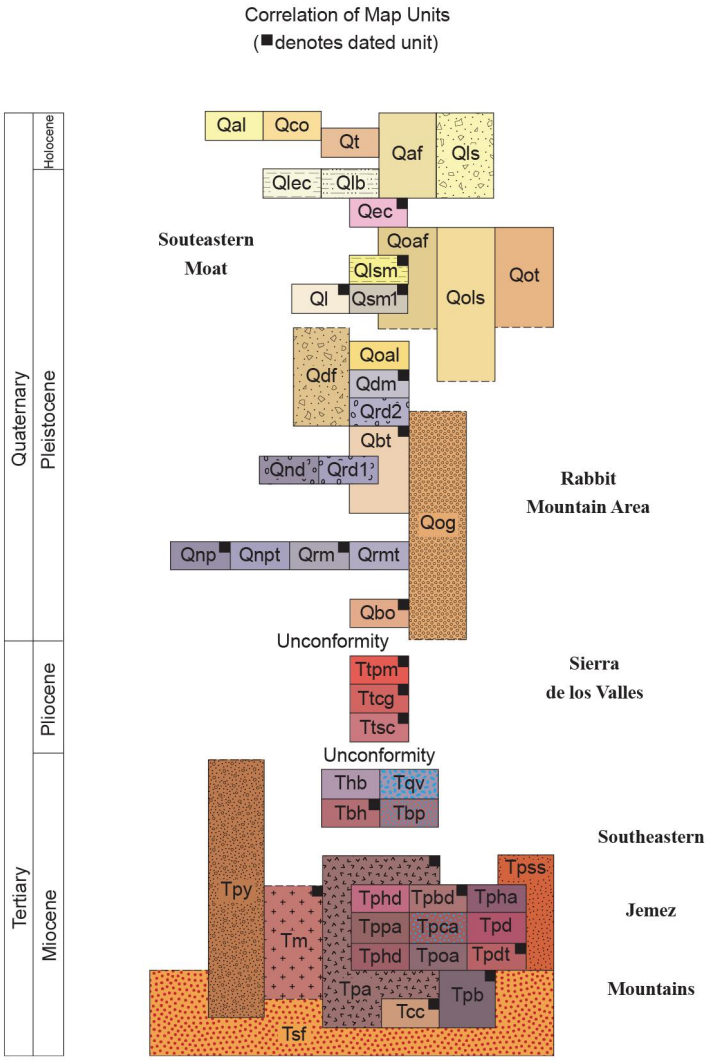
Preliminary Geologic Map of the Bland Quadrangle

Goff, F., Reneau, S.L., Lynch, S., Goff, C.J., Gardner, J.N., Drakos, P., and Katzman, D., 2012, Preliminary Geologic Map of the Bland Quadrangle, Los Alamos and Sandoval Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 112, 1:24000 scale (*GRI Source Map ID 7225*)

Report

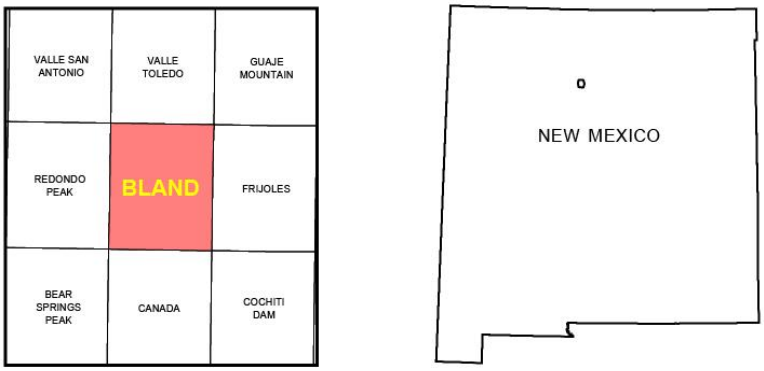
The geologic report and map for this publication are available from the New Mexico Bureau of Geology and Mineral Resources here: http://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?Volume=112

Correlation



Extracted from: (OF-GM 112).

Index and Location Map



QUADRANGLE LOCATION

Extracted from: (OF-GM 112).

Legend

Explanation of Map Symbols

A — A'	Location of geologic cross section.
	Geologic contact. Solid where exposed or known, dashed where approximately known, queried where uncertain.
	Normal fault, ball-and-bar on downthrown side. Solid where exposed, dashed where approximately known, dotted where concealed.
	Strike and dip of volcanic foliation.
	Sheared or brecciated rock.
	Volcanic vent. Queried where uncertain.
	Landslide. Arrow shows direction of movement.
	Cold spring.
X 1.43	Sample location and date on fresh rock in millions of years.
X 1.43a	Sample location and date on altered rock in millions of years.

Ep	Vug/vein epidote	Z	Fiberous zeolite
Fe	Iron oxidation	Mn	Abundant pyrolusite
Si	Quartz/chalcedony	Py	Abundant pyrite

Extracted from: (OF-GM 112).

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Bailey, R., Smith, R., and Ross, C., 1969, Stratigraphic nomenclature of volcanic rocks in the Jemez Mountains, New Mexico: *U.S. Geological Survey Bulletin 1274-P*, 19 pp.

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Goff, F. and Gardner, J. N., 2004, Late Cenozoic geochronology of volcanism and mineralization in the Jemez Mountains and Valles caldera, north central New Mexico: *in*: Mack, G. and Giles, K. (*eds.*), *The Geology of New Mexico —A Geologic History*, New Mexico Geological Society, Special Publication 11, p. 295-312.

Griggs, R., 1964, Geology and groundwater resources of the Los Alamos area, New Mexico: *U.S. Geological Survey Water-supply Paper 1753*, 107 pp.

Wolff, J. A., Rowe, M.C., Teasdale, R., Gardner, J. N., Ramos, F. C., and Heikoop, C. E., 2005, Petrogenesis of pre-caldera mafic lavas, Jemez Mountains volcanic field (New Mexico, USA): *Journal of Petrology*, v. 46, p. 407-439.

Extracted from: (OF-GM 112).

Geologic Map of the Cochiti Dam Quadrangle

Dethier, D.P., Thompson, R.A., Hudson, M.R., Minor, S.A., and Sawyer, D.A., 2011, Geologic Map of the Cochiti Dam Quadrangle, Sandoval County, New Mexico, U.S. Geological Survey, Scientific Investigations Map SIM-3194, 1:24,000 scale. (*GRI Source Map ID 7228*)

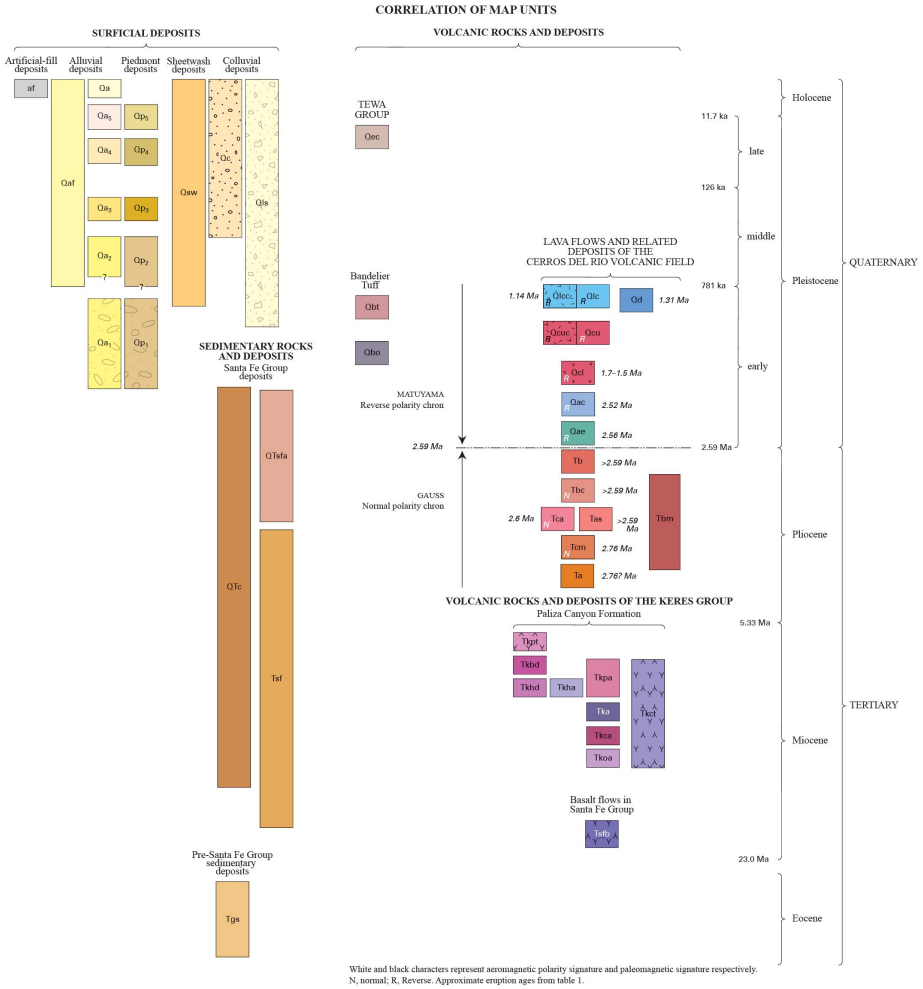
Introduction

The Cochiti Dam quadrangle is located in the southern part of the Española Basin (fig. 1) and contains sedimentary and volcanic deposits that record alluvial, colluvial, tectonic and volcanic processes over the past seventeen million years. The geology was mapped from 1997 to 1999 and modified from 2004 through 2008. The primary mapping responsibilities were as follows: Dethier mapped the surficial deposits, basin-fill sedimentary deposits, Miocene to Quaternary volcanic deposits of the Jemez volcanic field, and a preliminary version of fault distribution. Thompson and Hudson mapped the Pliocene and Quaternary volcanic deposits of the Cerros del Rio volcanic field. Thompson, Minor, and Hudson mapped surface exposures of faults and Hudson conducted paleomagnetic studies for stratigraphic correlations. Thompson prepared the digital compilation of the geologic map.

The mapped distribution of units is based primarily on interpretation of 1:16,000-scale, color aerial photographs taken in 1992, and 1:40,000-scale, black-and-white, aerial photographs taken in 1996 (U.S. Geological Survey National Aerial Photography Program (NAPP) available at http://eros.usgs.gov/#/Guides/napp). Most of the contacts on the map were transferred from the aerial photographs using a photogrammetric stereoplotter and subsequently field checked for accuracy and revised based on field determination of allostratigraphic and lithostratigraphic units. Determination of lithostratigraphic units in volcanic deposits was aided by geochemical data, 40Ar/39Ar geochronology, aeromagnetic and paleomagnetic data (Grauch and Bankey, 2003; Grauch and others, 2006; Thompson and others, 2006). Supplemental revision of mapped contacts was based on interpretation of U.S. Geological Survey (USGS) 1-meter orthoimagery. This version of the Cochiti Dam quadrangle geologic map uses the USGS 1:24,000-scale Cochiti Dam, New Mexico quadrangle as the topographic base overlain on a screened shaded relief base generated from 10-m digital elevation model (DEM) data from the USGS National Elevation Dataset (NED, http://ned.usgs.gov/); sun illumination is from the northwest at 45° above the horizon.

For continuity, geologic units are delineated in areas now inundated by Cochiti Lake and in areas where natural topography was altered by excavation of material used in the construction of Cochiti Dam. Contacts in these areas are drawn using topography mapped in 1953, guided by aerial-photographic interpretation and mapping in adjacent areas. Northwest of the Pajarito fault zone in the northwest part of the map area, contacts and map unit descriptions were derived largely from Goff and others (1990). Major tributary canyons to the Rio Grande are labeled in figure 2 and a simplified fault diagram is shown as figure 3.
Extracted from: (SIM 3194).

Correlation



Extracted from: (SIM 3194).

Landsat Image 1

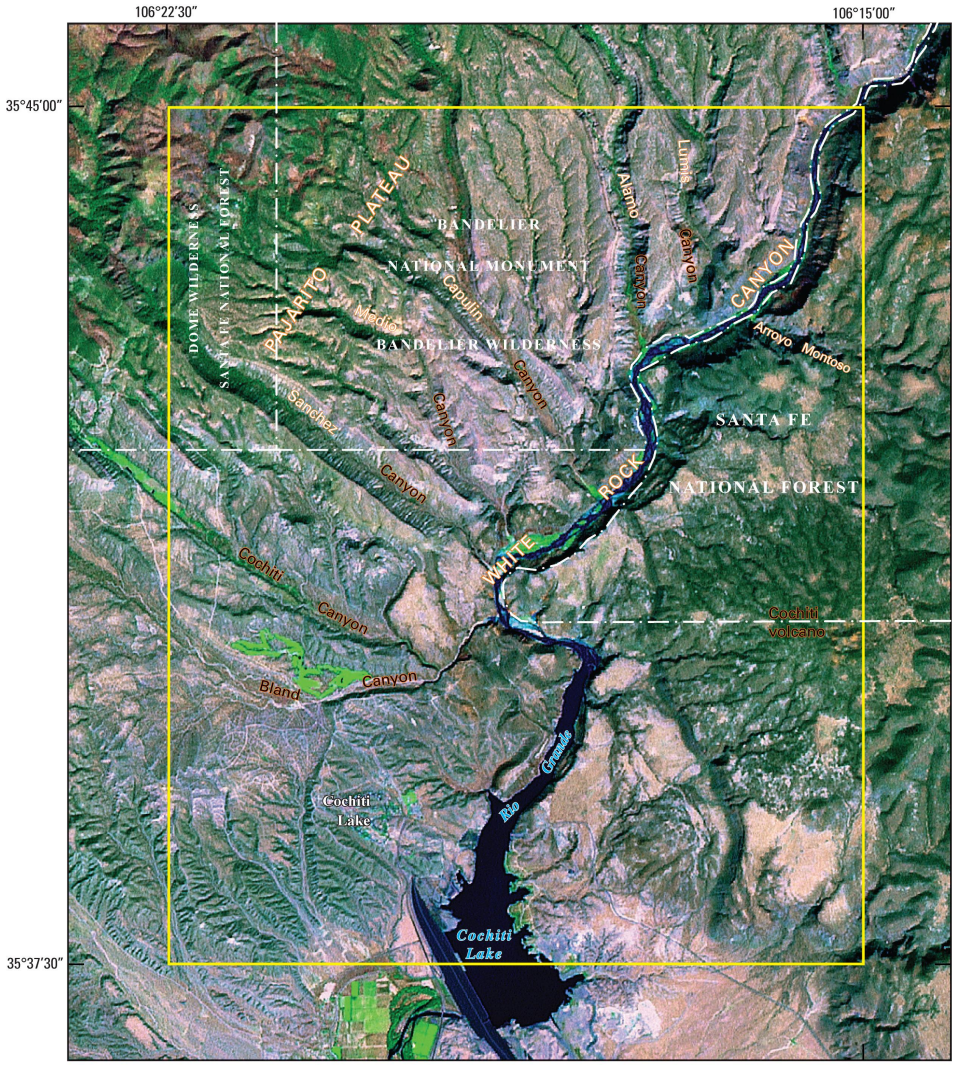


Figure 2. Landsat 7 satellite image (30-m band 7–4–2 merged with 15-m band 8) acquired on October 14, 1999, of Cerros del Rio, New Mexico area (image clip from Sawyer and others, 2004), showing select geologic features and geographic names. Yellow rectangle is the boundary of the Cochiti Dam 7.5-minute quadrangle.

Extracted from: (SIM 3194).

Landsat Image 2

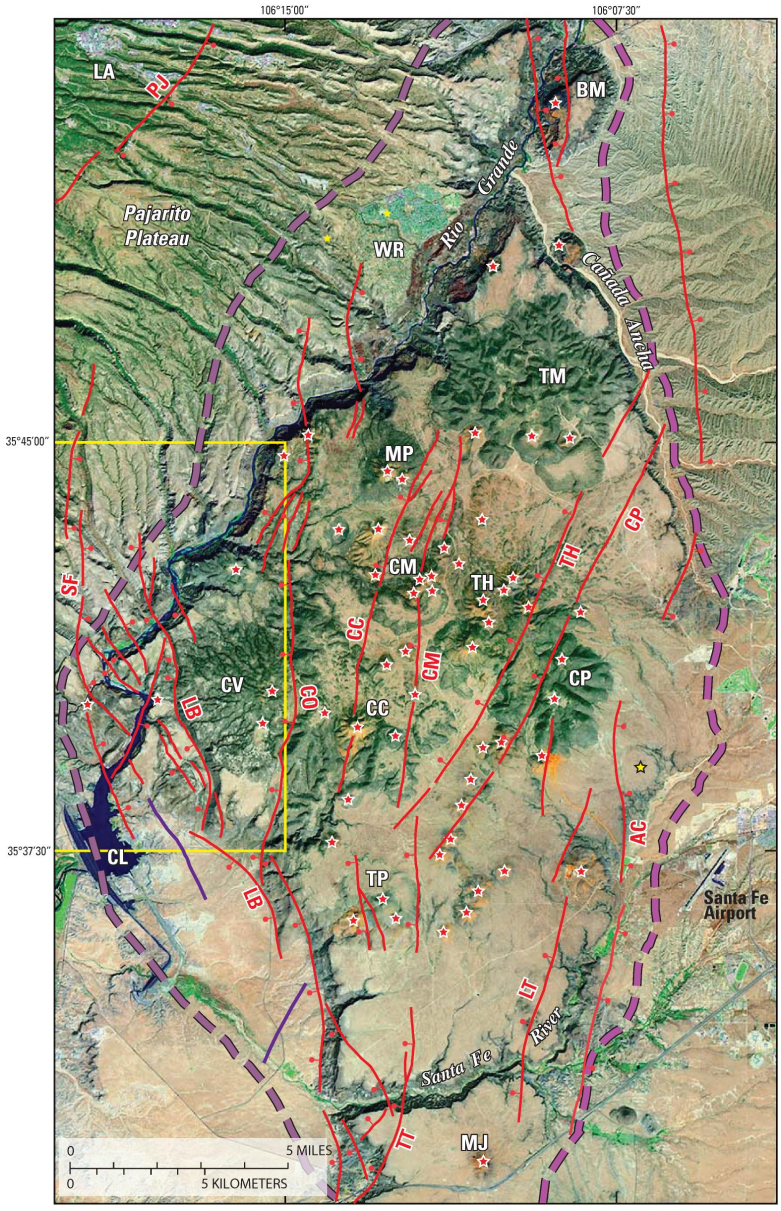


Figure 3. Landsat 7 image (30-m band 7–4–2 merged with 15-m band 8) acquired on October 14, 1999; image clip from Sawyer and others (2004) of Cerros del Rio volcanic field showing approximate eruptive extent as purple dashed line, mapped vent areas as red stars, and presumed buried vents based on aeromagnetic data as yellow stars. Geographic abbreviations: LA, Los Alamos; WR, White Rock; CL, Cochiti Lake; BM, Buckman Mesa; OM, Ortiz Mountain; MP, Montoso Peak; CM, Cerro Micho; TH, Twin Hills; CP, Cerro Portillo; CC, Cerro Colorado; CV, Cochiti Volcano; TP, Tetilla Peak; MJ, Mesita de Juana. Major mapped faults and lineaments are shown in red and aeromagnetic lineaments related to buried faults are shown in purple. Fault abbreviations: PJ, Pajarito fault; SF, San Francisco fault; LB, La Bajada fault; TT, Tetilla fault; CM, Cerro Micho fault; CC, Cerro Colorado fault; CO, Cochiti fault; TH; Twin Hills fault; CP, Cerro Portillo fault; LT, Las Tetillitas fault; AC, Arroyo Calabasas fault. Quadrangle outline in yellow.

Extracted from: (SIM 3194).

Table 1 - Characteristics of Cerros del Rio Volcanic Field Deposits

Table 1. *Map units, eruption ages, and volcanic rock names for the Cerros del Rio volcanic field deposits.*

Map unit name	Map unit symbol	Eruptive series	Eruption Age[1] (Ma)	Volcanic rock name[2]
Andesite of Little Cochiti cone	Qlc	3	1.14	Trachyandesite
Dacite of Arroyo Montoso	Qd	3	1.31	Dacite/trachyte
Upper andesite of Cochiti volcano	Qcu	3	1.51	Andesite/trachyandesite
Lower andesite of Cochiti volcano	Qcl	3	1.7–1.5	Andesite/basaltic andesite
Basaltic andesite of Cochiti Lake	Qac	2	2.52	Basaltic trachyandesite
Basaltic andesite of Arroyo Eighteen	Qae	2	2.56	Basaltic trachyandesite
Basalt of La Bajada Rim	Tb	1	>2.59	Basalt/basaltic andesite
Basalt of Cochiti Lake	Tbc	1	>2.59	Basalt
Andesite of Sanchez Canyon	Tas	1	>2.59	Andesite/trachyandesite
Andesite of Colorado Peak	Tca	1	2.6	Trachyandesite
Andesite of Cerro Micho	Tcm	1	2.76	Trachyandesite
Andesite and basaltic andesite, undivided	Ta	1	>2.76?	Andesite/trachyandesite /basaltic andesite

[1]Eruption ages are based on one or more ages where determined for the map area or estimated based on stratigraphic position

[2]Modified root names based on IUGS rock classification (LeBas and Streckeisen, 1991)

Extracted from: (SIM 3194).

Table 2 - Geologic Sample Coordinates

Table 2. *Locations for samples referenced in the text*

Sample no.	Quadrangle	Map unit	*Latitude	*Longitude
96TCD08	Cochiti Dam	Qlc	35º38' 48"	106º16'43"
DN85113	Cochiti Dam	Qd	35º43'05"	106º16'16"
3MRG3	Cochiti Dam	Qcu	35º41'13"	106º16'33"
DN9612	Cochiti Dam	Qac	35º38'32"	106º19'11"
3MRG6	Montoso Peak	Qae	35º42'57"	106º14'07"
96TMP38	Montoso Peak	Tca	35º39'49"	106º13'10"
3MRG5	Montoso Peak	Tcm	35º43'01"	106º13'57"

*Geographic Coordinate System NAD 27 Datum

Extracted from: (SIM 3194).

Location and Generalized Geologic Map

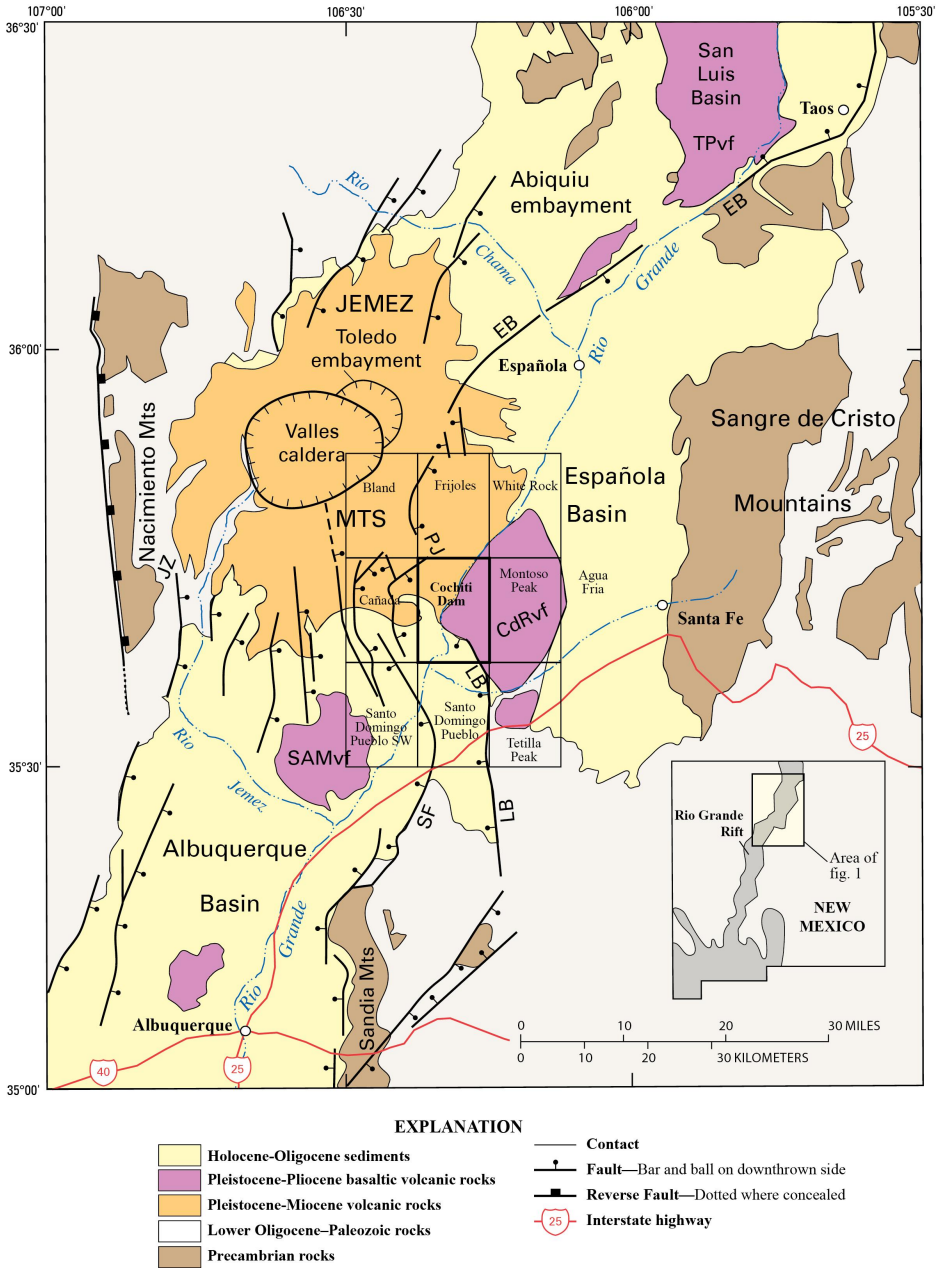
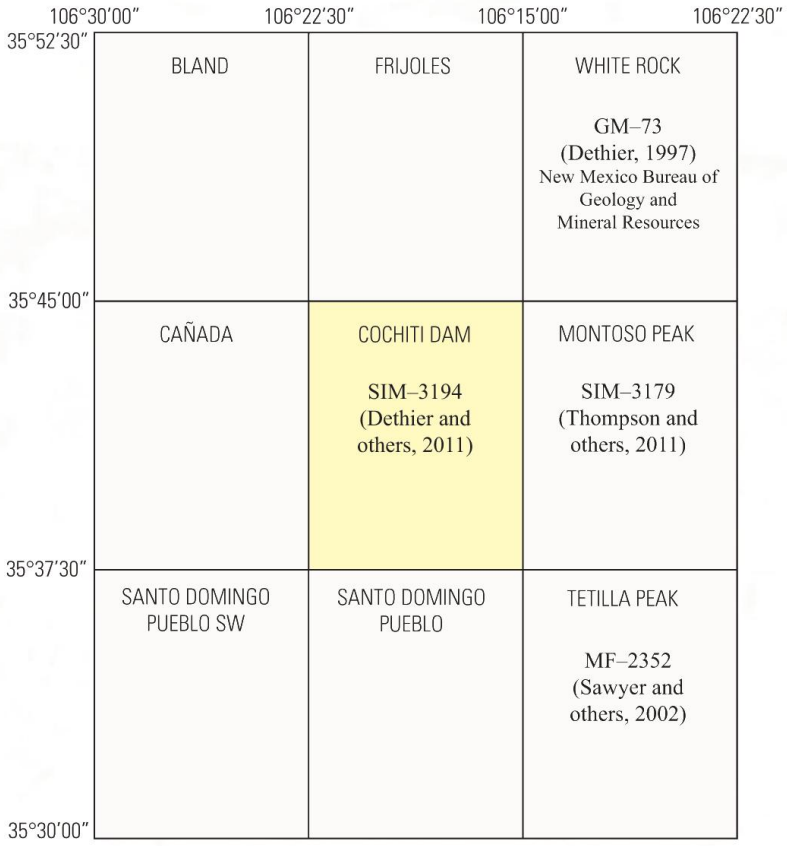


Figure 1. Location map and general geology of the Española Basin, adjacent basin, and volcanic fields of the Rio Grande rift. Geology modified from Smith and others (2001, fig. 3). Approximate location of the Toledo caldera (Toledo embayment) is modified from Gardner and Goff (1996). Volcanic fields: CdRvf, Cerros del Rio volcanic field; SAMvf, Santa Ana Mesa volcanic field; TPvf, Taos Plateau volcanic field. Faults: EB, Embudo fault, JZ, Jemez fault; LB, La Bajada fault; PJ, Pajarito fault; SF, San Francisco fault.

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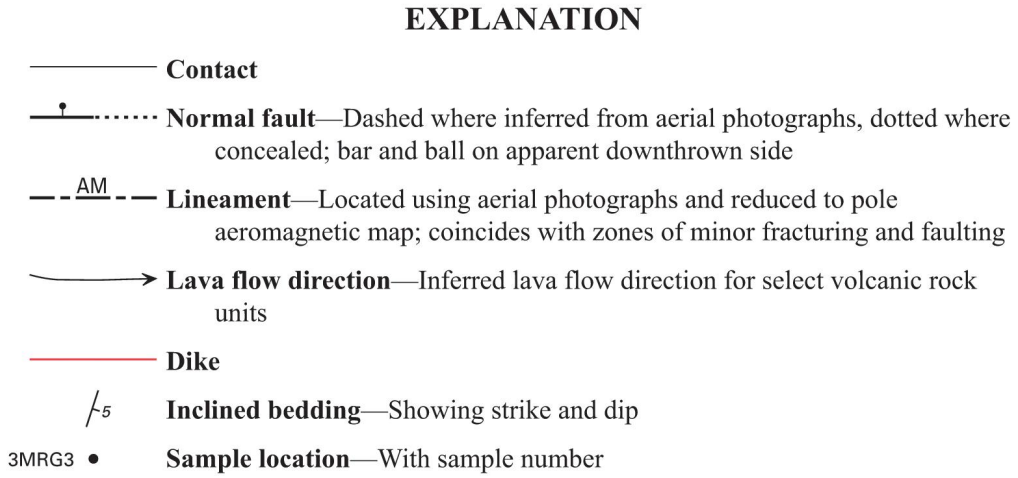
Index Map



Index map showing Cochiti Dam quadrangle, in yellow, and adjacent 7.5-minute quadrangles. For U.S. Geological Survey publications, number, authorship, and date of publication are shown; for the non-U.S. Geological Survey publication, number, authorship, year of publication, and affiliation are shown.

Extracted from: (SIM 3194).

Legend



Extracted from: (SIM 3194).

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Extracted from: (SIM 3194).

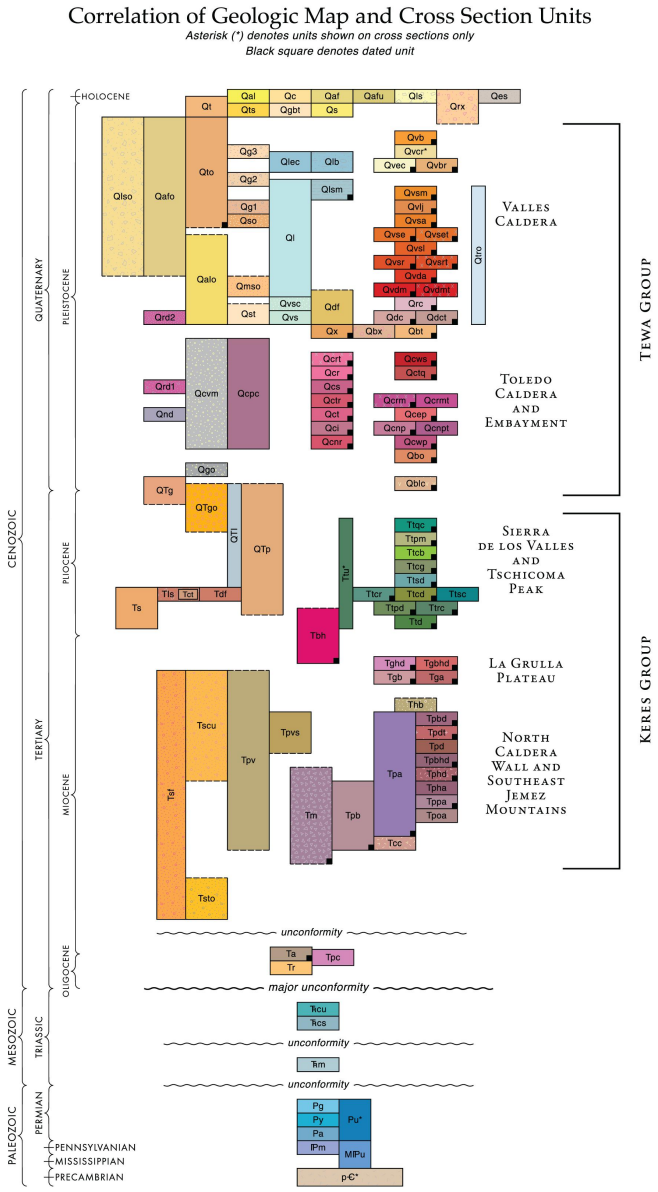
Geologic Map of the Valles Caldera

Goff, Fraser, Gardner, J.N., Reneau, S.L., Kelley, S.A., Kempter, K.A., and Lawrence, J.R., 2011, Geologic Map of the Valles Caldera, Jemez Mountains, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Geologic Map 79, 1:50000 scale. (*GRI Source Map ID 75592*)

Report

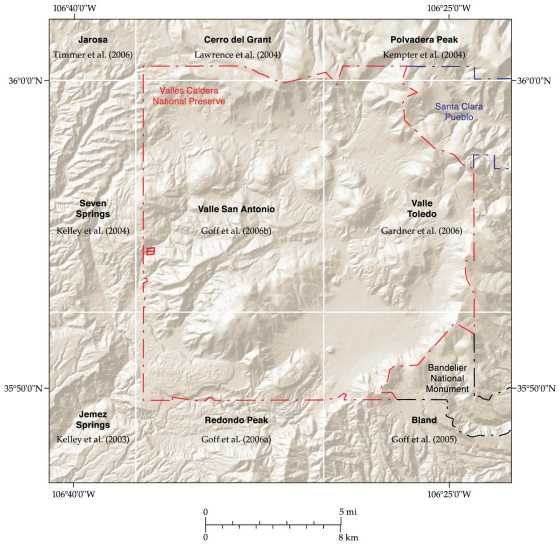
The geologic report and map for this publication are available from the New Mexico Bureau of Geology and Mineral Resources here: http://geoinfo.nmt.edu/repository/index.cfml?rid=20110002

Correlation



Extracted from: (GM 79).

Index and Location Map



Key to the new geologic quadrangles used to construct this map.



INDEX MAP OF NEW MEXICO

Extracted from: (GM 79).

Legend

Map Symbols

Contact—Dashed where approximately located

Normal fault—Showing dip; bar and ball on downthrown side; dashed where approximately located; dotted where concealed; queried where inferred

Reactivated fault—Faults that have changed direction of motion or that have moved at different times during rifting, collapse and resurgence. *(Cross sections only)*

Paleo beach ridge

Landslide direction

Isotherm *(Cross sections only)*

Horizontal bedding

Strike and dip of inclined bedding

Strike and dip of inclined foliation

Strike and dip of vertical foliation

Strike and dip of inclined joint

Vent—From either surface evidence or inferred from topography

Spring

Fumarole

Bog

Well

Location and age of fresh sample

Location and age of altered sample

Mine

Geologic cross section

Major drainage

Valles Caldera National Preserve boundary

Bandelier National Monument boundary

Santa Clara Pueblo boundary

State highway

Valles Caldera National Preserve road (unpaved)

National Forest Service road (unpaved)

Bureau of Indian Affairs road (unpaved)

County road (unpaved)

Extracted from: (GM 79).

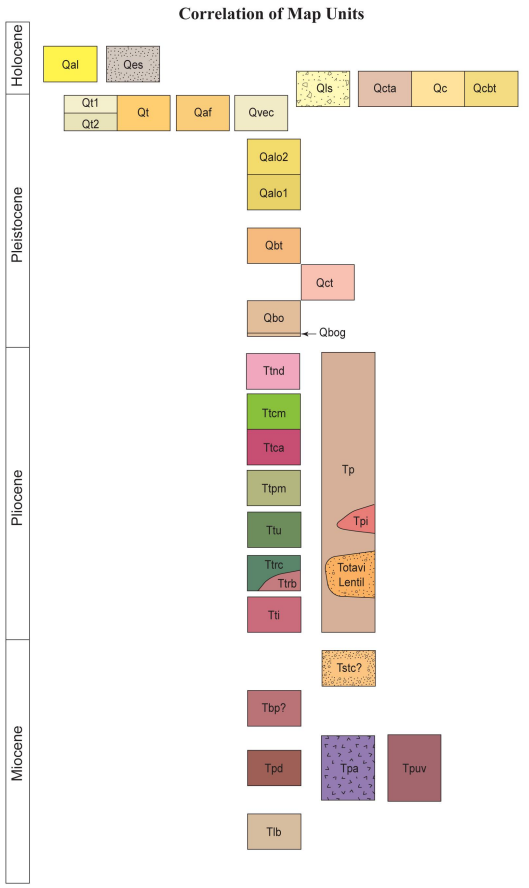
Geologic Map of the Guaje Mountain Quandrangle

Kempter, K.A., Kelley, S., Gardner, J.N., Reneau, S.L., Broxton, D.E., Goff, F., Levine, A. and Lewis, C., 2011, Geologic Map of the Guaje Mountain Quadrangle, Los Alamos and Sandoval Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 55, 1:24000 scale (*GRI Source Map ID 6633*)

Report

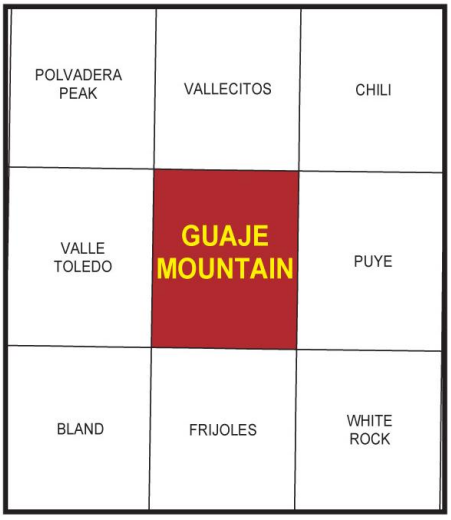
The geologic report and map for this publication are available from the New Mexico Bureau of Geology and Mineral Resources here: http://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?Volume=55

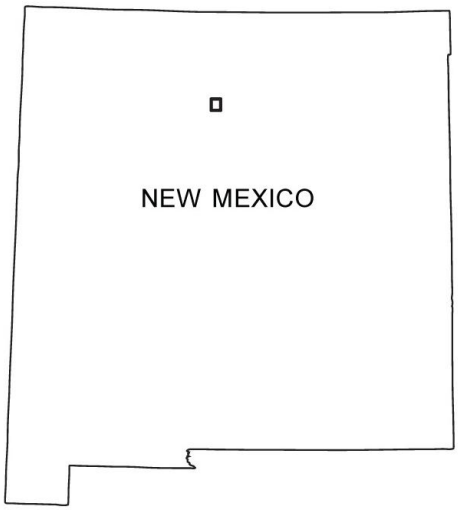
Correlation



Extracted from: (OF-GM 55).

Index and Location Map

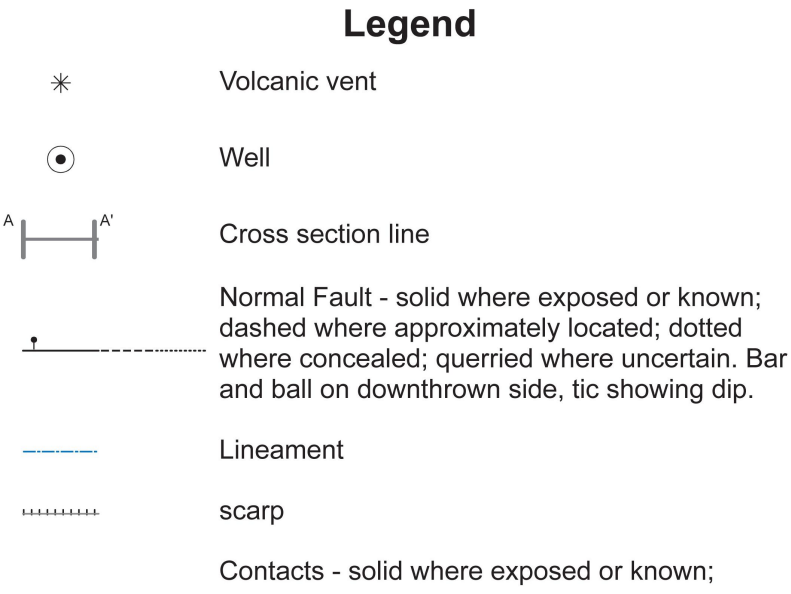




QUADRANGLE LOCATION

Extracted from: (OF-GM 55).

Legend

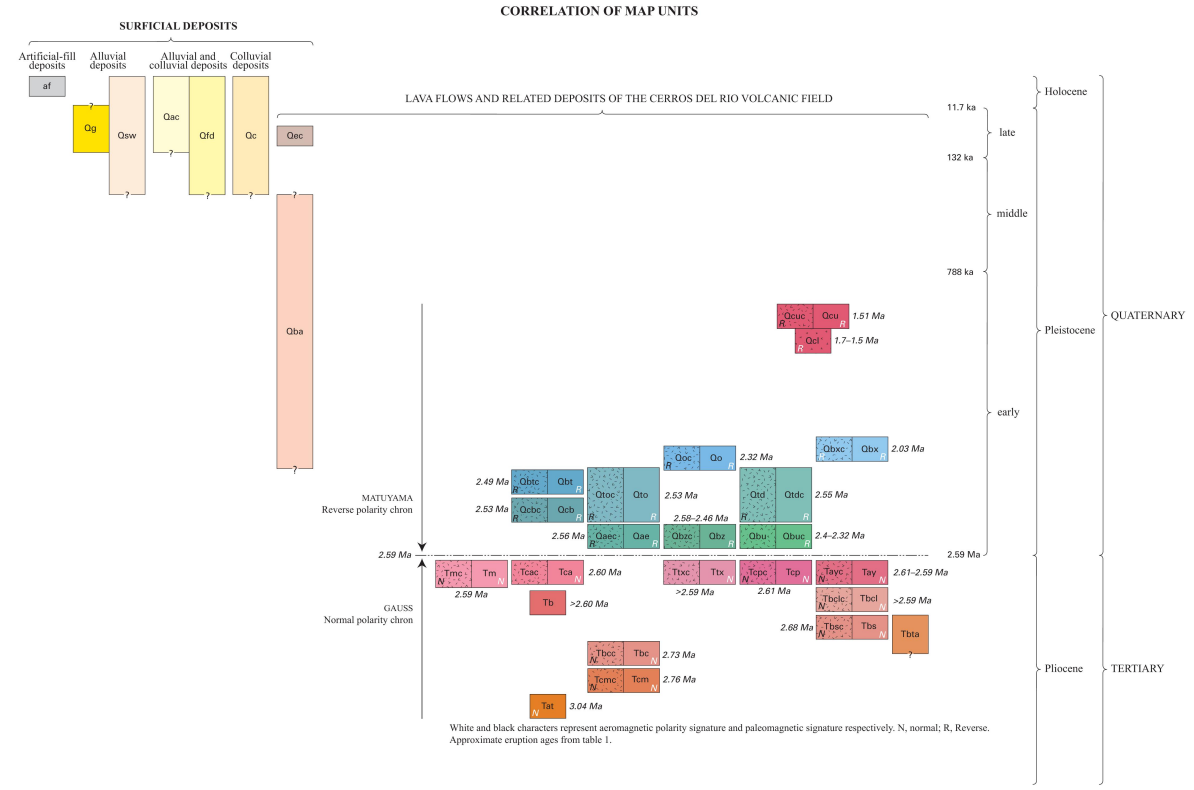


Extracted from: (OF-GM 55).

Geologic Map of the Montoso Peak Quadrangle

Thompson, R. A., Hudson, M.R., Shroba, R.R., Minor, S.A., and Sawyer, D.A., 2011, Geologic Map of the Montoso Peak Quadrangle, Santa Fe and Sandoval Counties, New Mexico, U.S. Geological Survey, Scientific Investigations Map SIM-3179, 1:24000 scale. (*GRI Source Map ID 75593*)

Correlation



Extracted from: (SIM 3179).

Table 1 - Characteristics of Cerros del Rio Volcanic Field Deposits

Table 1. *Map units, eruption ages, and volcanic rock names for the Cerros del Rio volcanic field*

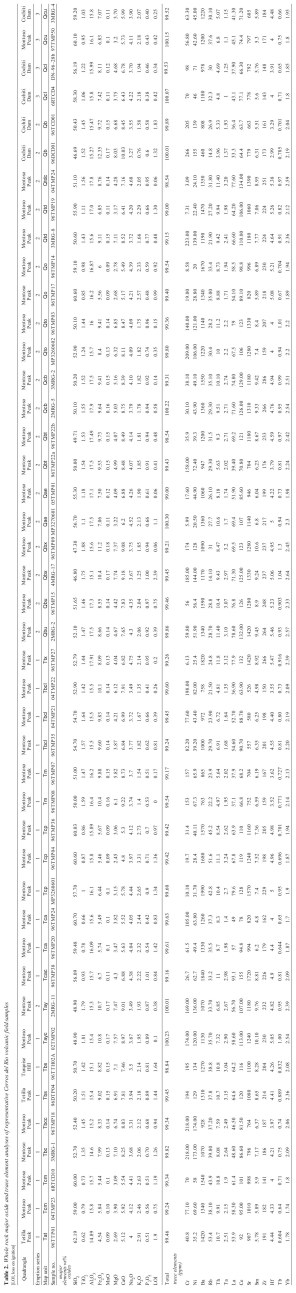
Map unit name	Map unit symbol	Eruptive series	Eruption age[1] (Ma)	Volcanic rock name[2]
Upper andesite of Cochiti Volcano	Qcu	3	1.51	Andesite/trachyandesite
Lower andesite of Cochiti Volcano	Qcl	3	1.7–1.5	Andesite/basaltic andesite
Basalt of Hill 7033	Qbx	2	2.03	Basalt
Andesite of Ortiz Mountain	Qo	2	2.32	Trachyandesite/trachyte
Basaltic andesite of Twin Hills	Qto	2	2.53	Basaltic trachyandesite
Basalt of Hill 7065	Qtd	2	2.55	Basaltic trachyandesite/trachybasalt
Basalt of Tetilla Hole	Qbt	2	2.49	Trachybasalt
Basalt of Colorado Peak	Qcb	2	2.53	Trachybasalt
Basaltic andesite of Arroyo Eighteen	Qae	2	2.56	Basaltic trachyandesite
Basalt of Hill 6929	Qbz	2	2.58>Qbz>2.46	Trachybasalt
Basalt of Canada Ancha, upper unit	Qbu	2	2.4>Qbu>2.32	Basaltic trachyandesite
Basalt of Montoso Peak	Tm	1	2.59	Basalt/trachybasalt
Andesite of Colorado Peak	Tca	1	2.6	Trachyandesite
Basalt of La Bajada Rim	Tb	1	>2.6	Basalt/basaltic andesite
Basaltic andesite of Thirty-One Draw	Ttx	1	>2.59	Basaltic trachyandesite
Andesite of Cerrita Portillo	Tcp	1	2.61	Trachyandesite
Basalt of Caja del Rio	Tay	1	2.61–2.59	Trachybasalt
Basalt of Arroyo Calabasas, lower unit	Tbcl	1	>2.59	Trachybasalt/tranchyandesite
Basalt of Tsinat Mesa	Tbs	1	2.68	Trachybasalt/basaltic trachyandesite
Basaltic andesite of Cerro Micho	Tbc	1	2.73	Basalt/basaltic trachyandesite
Andesite of Cerro Micho	Tcm	1	2.76	Trachyandesite
Andesite of Tetilla Peak	Tat	1	3.04	Trachyandesite/andesite

[1]Approximate eruption ages are based on one or more ages where determined for the map area or estimated based on stratigraphic postion. $^{40}Ar/^{39}Ar$ ages for select samples from each map unit are reported in the text.
[2]Modified root names based on IUGS rock classification (LeBas and Streckeisen, 1991).

Extracted from: (SIM 3179).

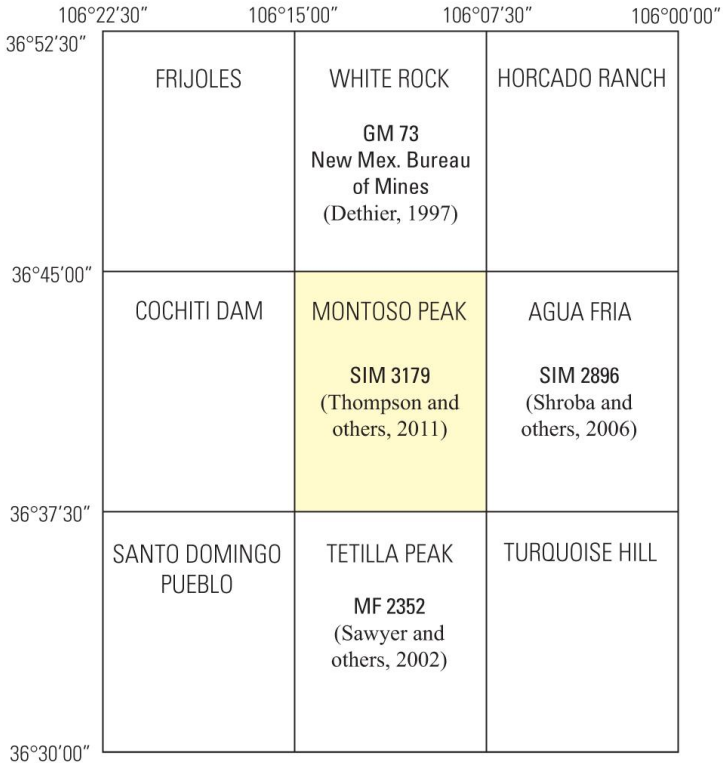
Table 2 - Analysis Data for Geologic Samples

Note: Users viewing the electronic version of this document can zoom in to view table details.



Extracted from: (SIM 3179).

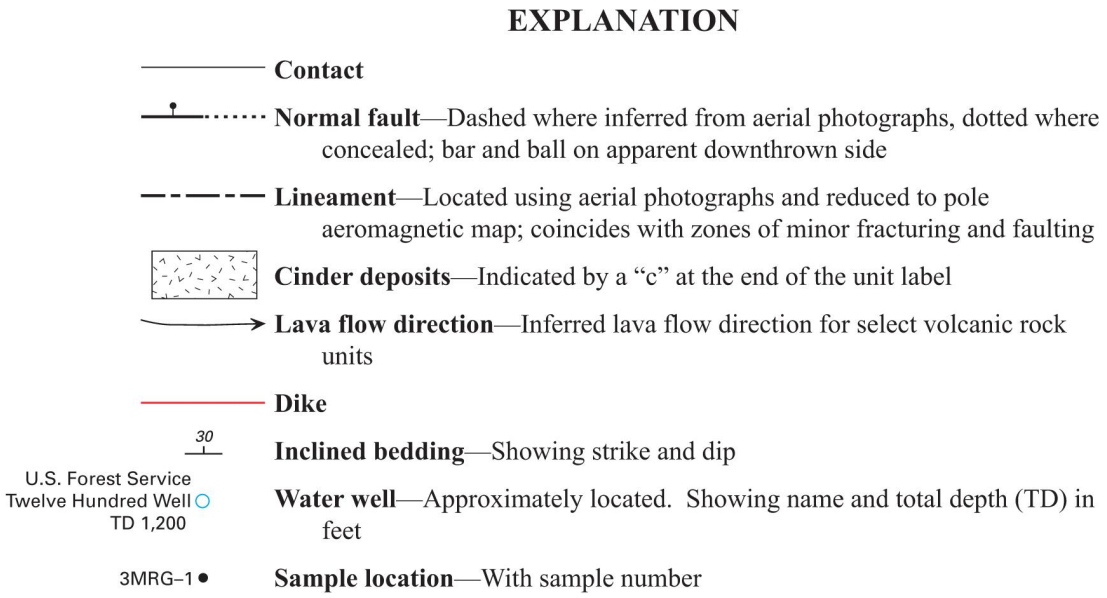
Index Map



Index map showing map area in yellow, and adjacent 7.5-minute quadrangles. For U.S. Geological Survey publications the publication number, author(s), and year of publication are shown. For non-USGS publications the State agency, author, and publication year are shown.

Extracted from: (SIM 3179).

Legend



Extracted from: (SIM 3179).

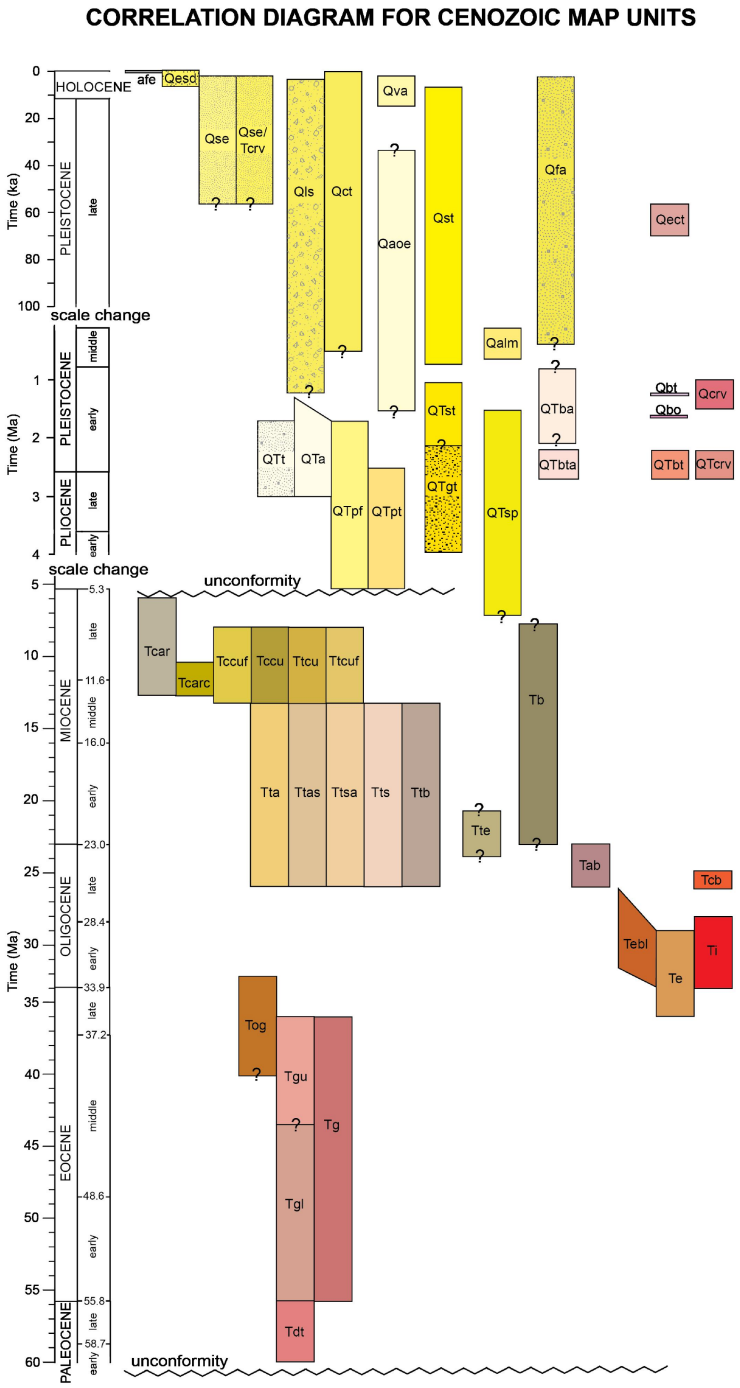
Geologic Map of the Southern Espanola Basin

Koning, D.J. and Read, A.S., 2010, Geologic Map of the Southern Espanola Basin, Santa Fe County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Report 531, 1:50000 scale. (*GRI Source Map ID 75477*)

Report

The geologic report and map for this publication are available from the New Mexico Bureau of Geology and Mineral Resources here: http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=531

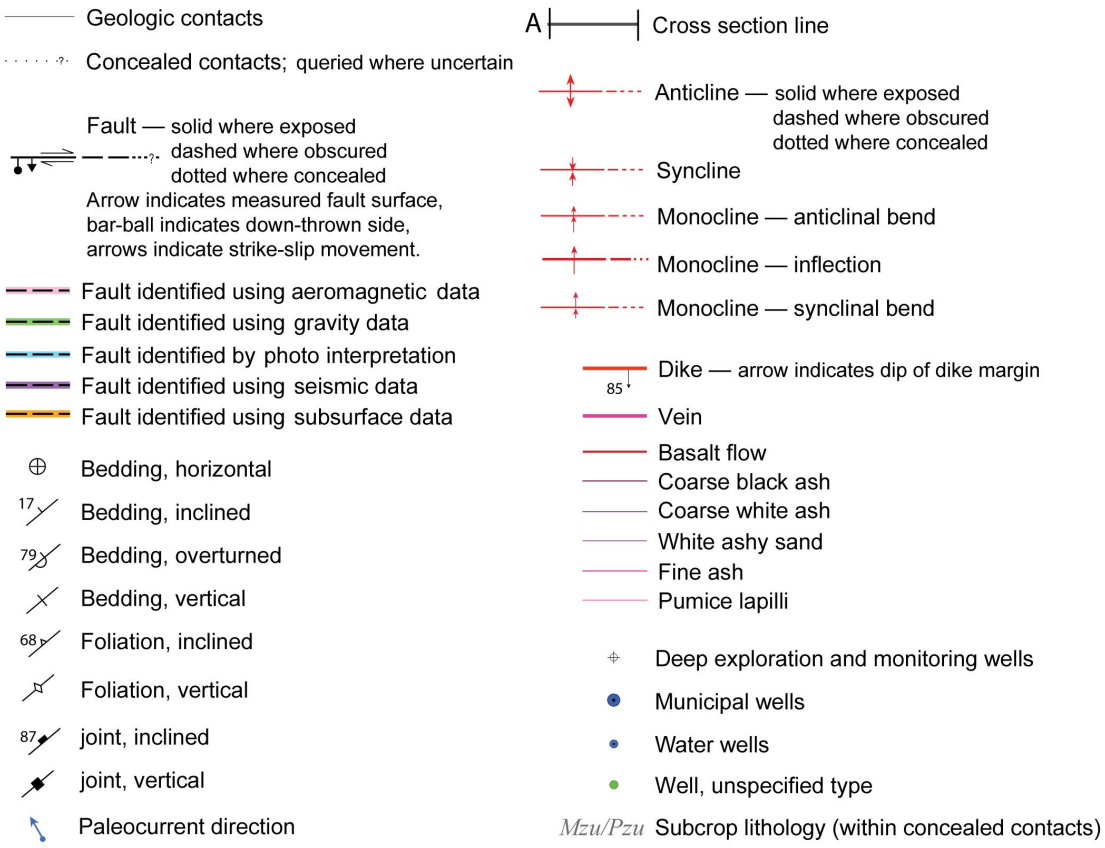
Correlation



Extracted from: (OFR 531).

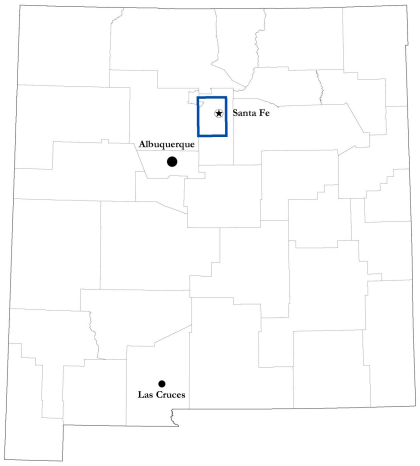
Legend

MAP SYMBOLS



Extracted from: (OFR 531).

Location Map and Source Map Index



Principal Sources of 7.5-minute Quadrangle Geologic Map Data

White Rock Dethier and Koning 2007	Horcado Ranch Koning, and Maldonado 2001	Tesuque Borchert, Skotnicki, and Read 1998	Aspen Basin Koning 2010
Montoso Peak Minor, [ed] 2006 Thompson, et al., [in prep]	Agua Fria Shroba 2005	Santa Fe Read, et al. 2000	McClure Reservoir Bauer, et al. 1996
Tetilla Peak Minor, [ed], 2006 and Sawyer et al. 2002	Turquoise Hill Koning and Hallett 2000	Seton Village Read, et al. 1999	Glorieta Ilg et al. 1997
Madrid Maynard, et al. 2001	Picture Rock Maynard,and Lisenbee 2001	Galisteo Lisenbee 1999	Booth 1977 Bull Canyon Koning and Read 2010

Extracted from: (OFR 531).

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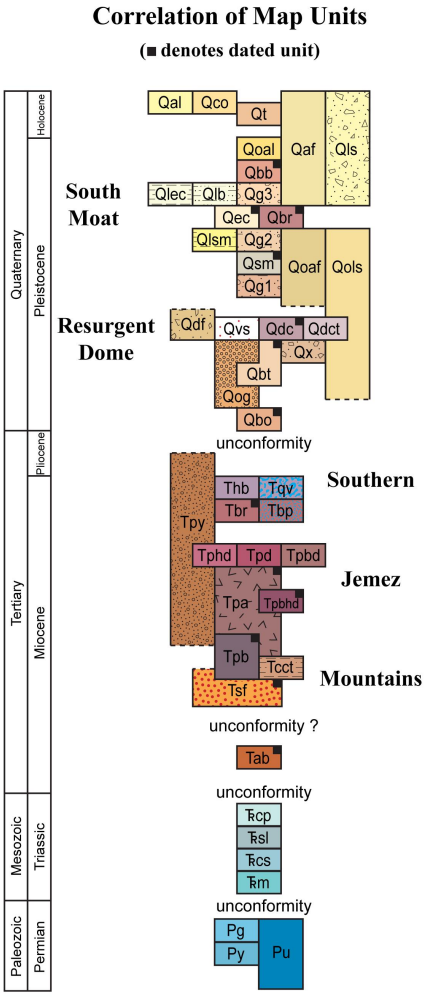
Preliminary Geologic Map of the Redondo Peak Quadrangle

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Report

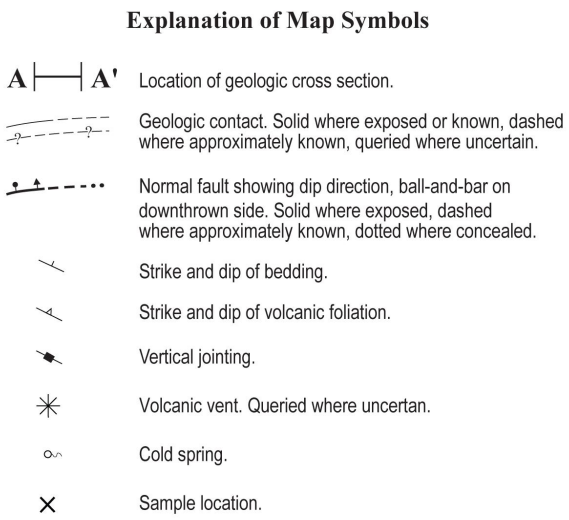
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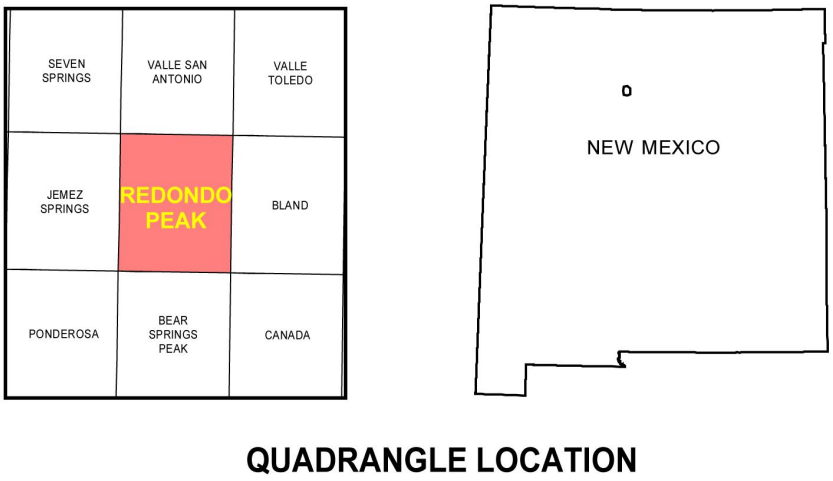
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Legend



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Index and Location Map



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Preliminary Geologic Map of the Canada Quadrangle

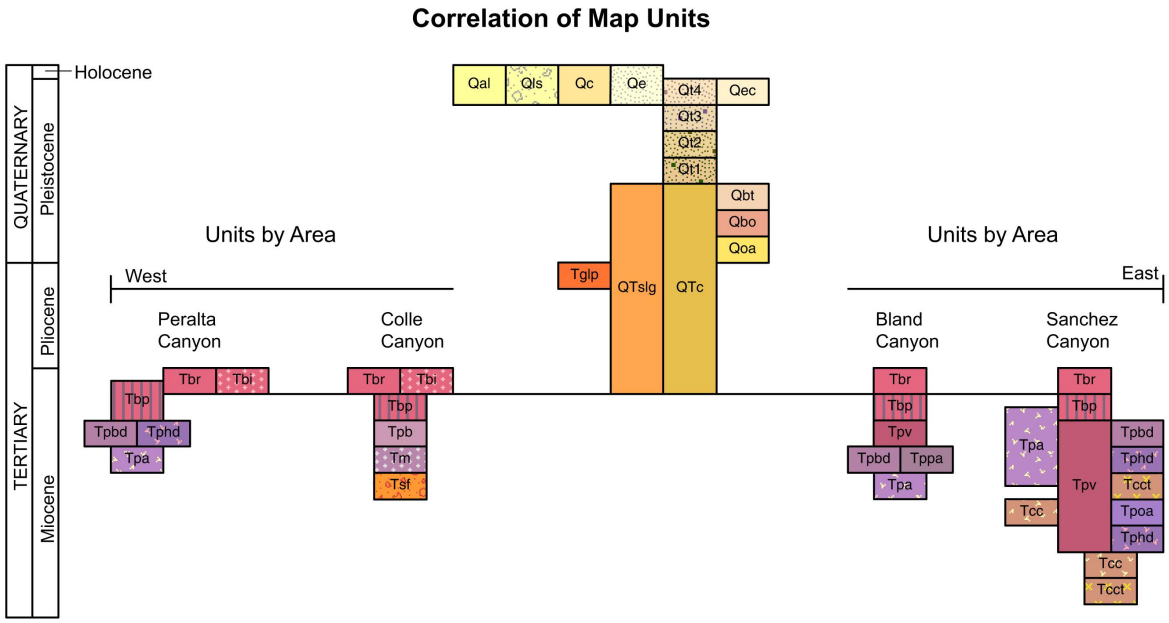
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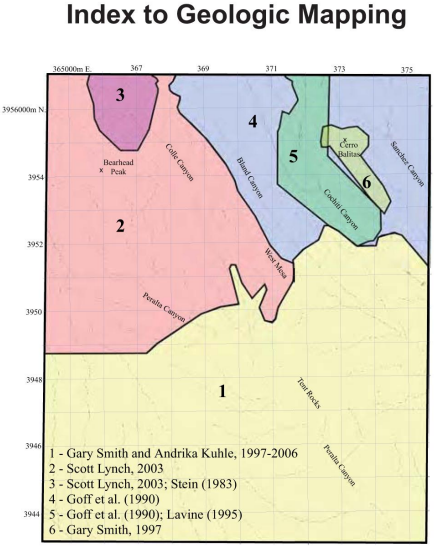
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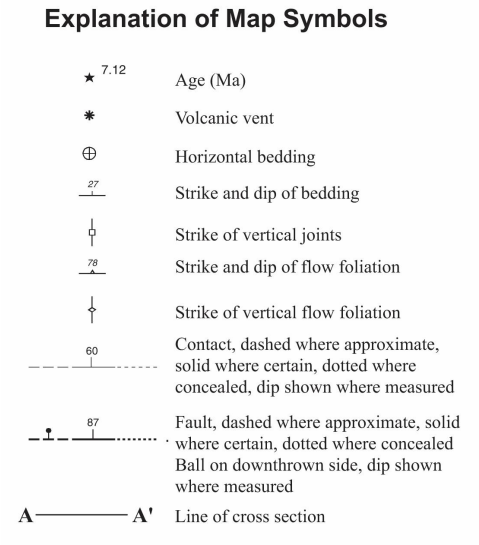
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Index of Map Sources



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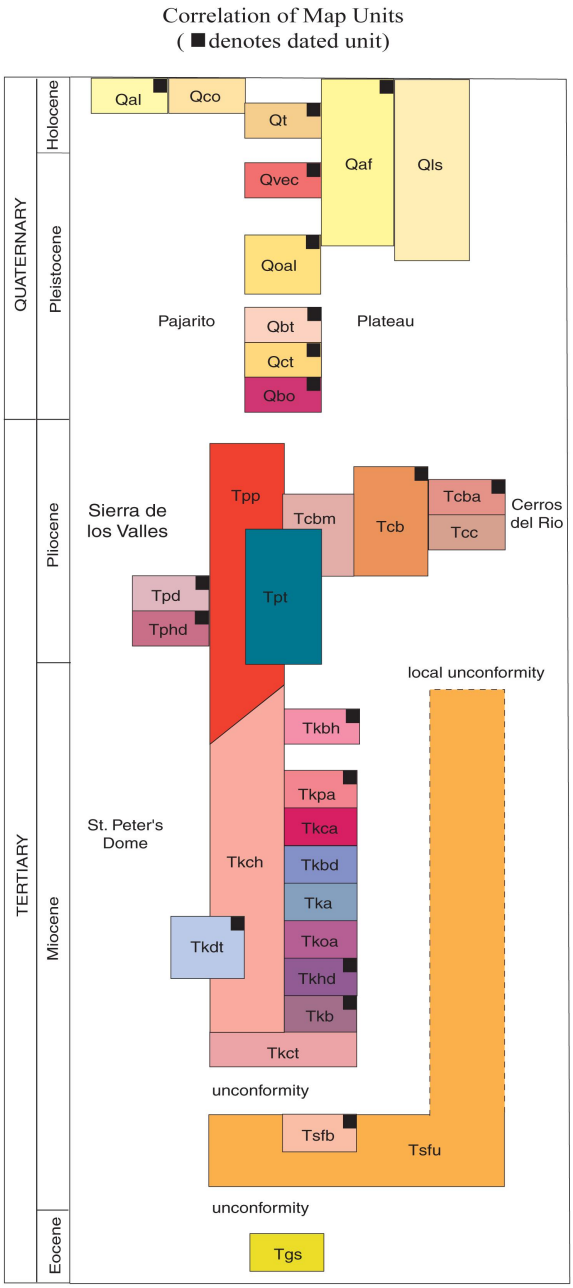
Preliminary Geologic Map of the Frijoles Quadrangle

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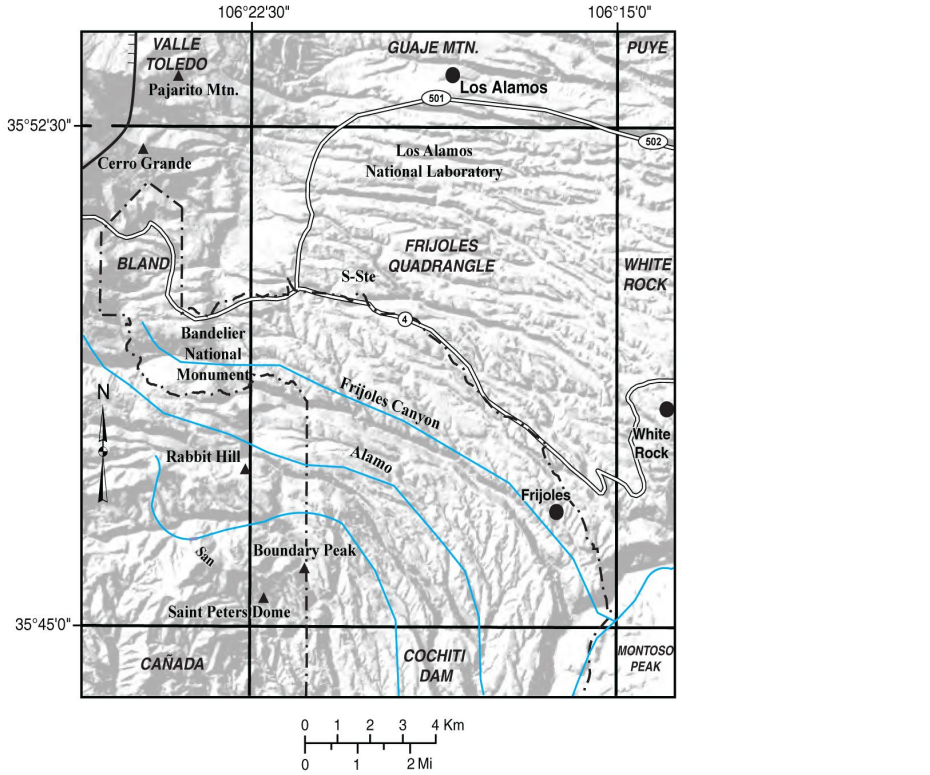
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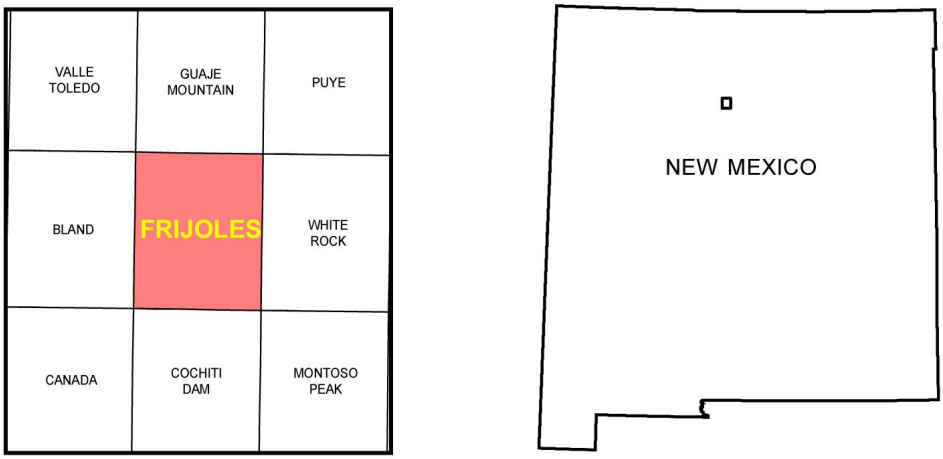
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Index and Location Map

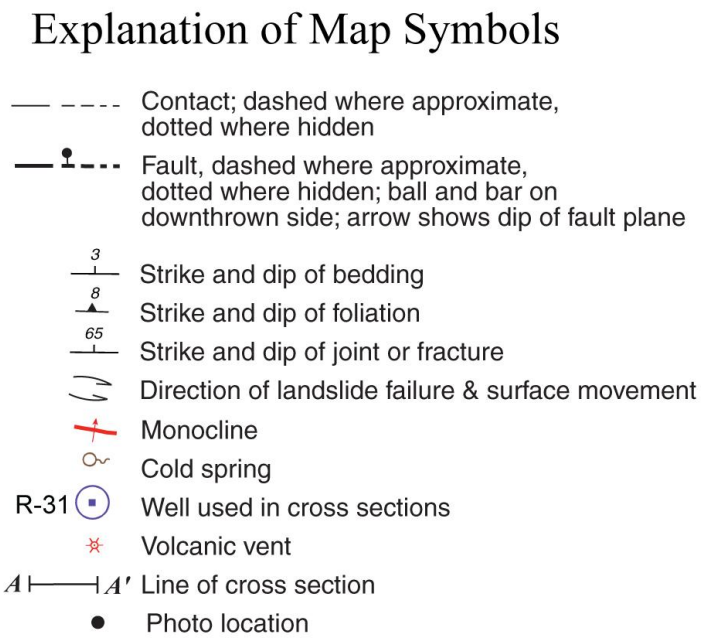




QUADRANGLE LOCATION

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Legend



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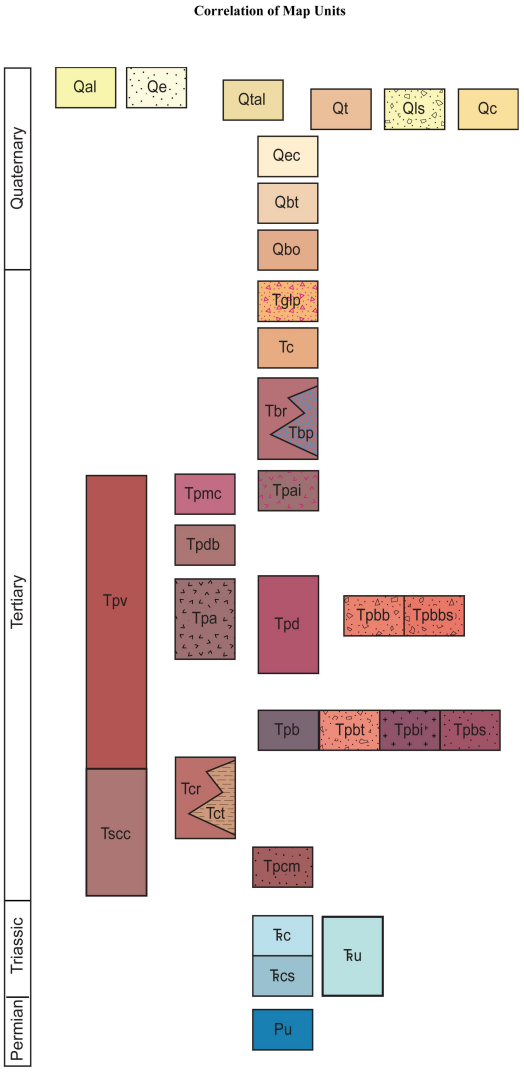
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Kempter, K.A., Osburn, R.O., Kelley, S., Rampey, M., Ferguson, C. and Gardner, J., 2007, Preliminary Geologic Map of the Bear Springs Peak Quadrangle, Sandoval County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 74, 1:24000 scale (*GRI Source Map ID 6630*)

Report

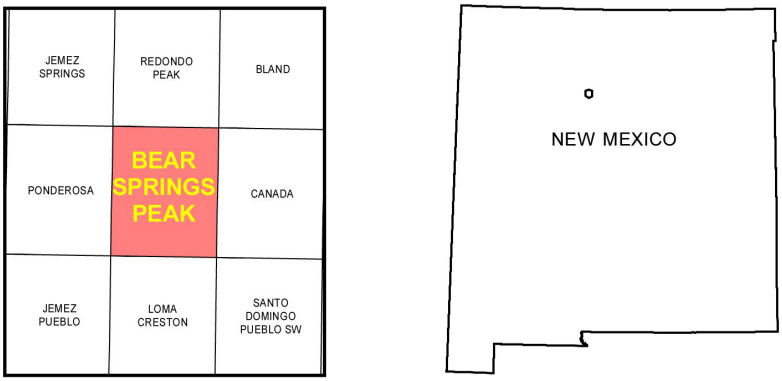
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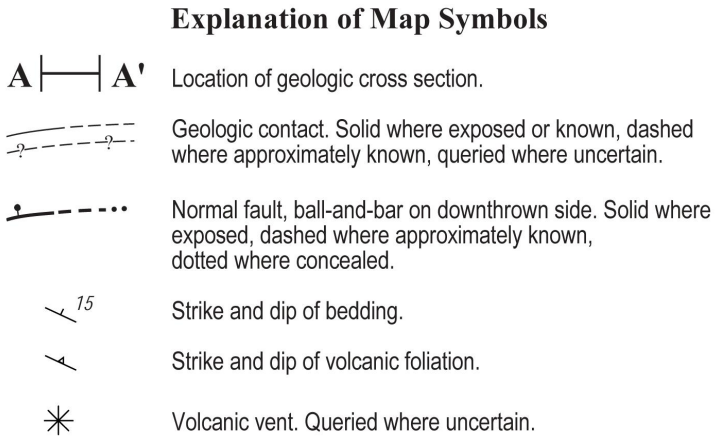
Index and Location Map



QUADRANGLE LOCATION

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Legend



Extracted from: (OF-GM 74).

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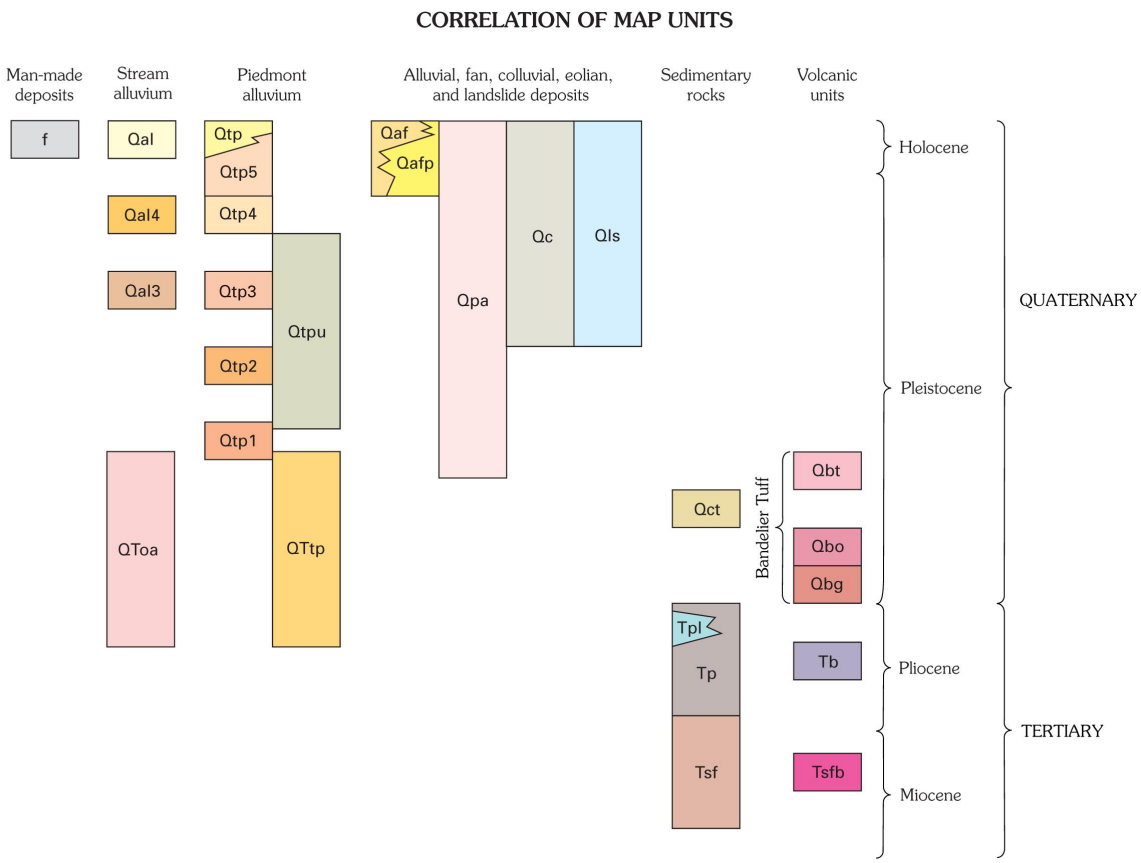
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Geologic Map of the Puye Quadrangle

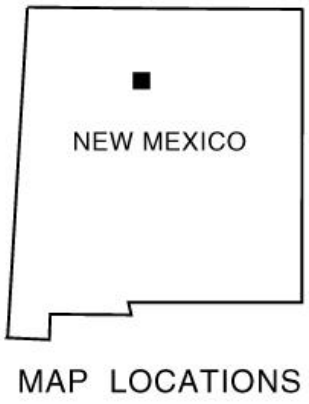
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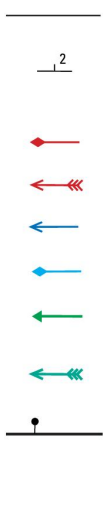
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Location Map



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Legend



Contact

Strike and dip of beds

Paleocurrent direction

Channels in lower part of Bandelier Tuff (Otowi Member; unit Qbo)

Piedmont alluvium of Cerro Toledo interval (unit Qct)

Puye Formation fanglomerate (unit Tp)

Puye Formation axial gravel (Totavi Lentil; part of unit Tp)

Santa Fe Group, upper part (undivided Chamita Formation; part of unit Tsf)

Santa Fe Group, lower part (undivided Tesuque Formation; part of unit Tsf)

Normal fault—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side. Note: North-trending fault in sec. 16 and 21, T. 20 N., R. 7 E., displaces unit Qpa and older units; colluvium of unit Qc lies against the degraded fault scarp

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GRI finalization by James Chappell (Colorado State University).

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).