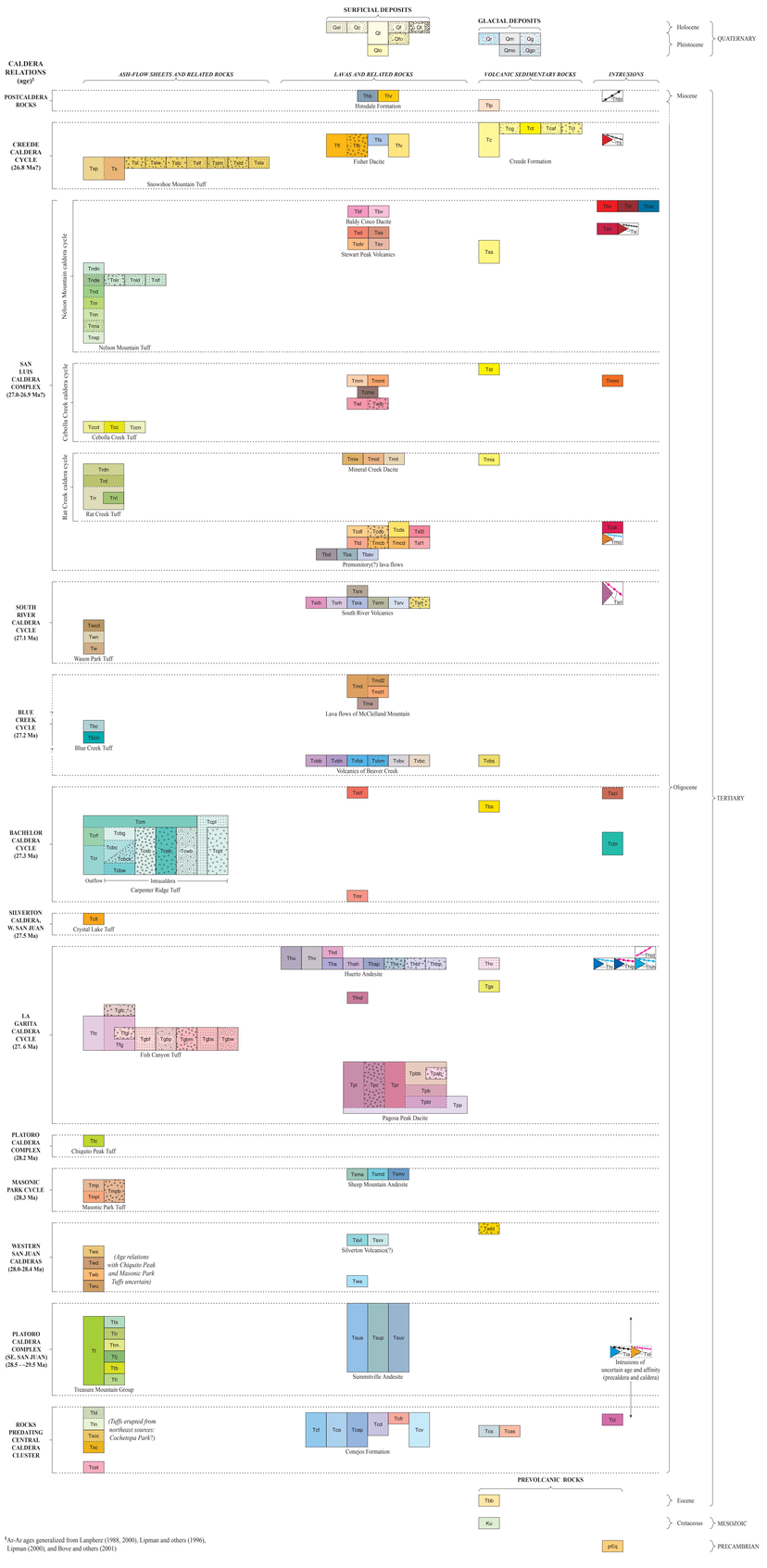
CORRELATION OF MAP UNITS

[Short-dashed boundaries indicate gradational welding or other emplacement contacts within eruptive units. Some major formation names are labeled. Some units of a formation are divided by emplacement type]



[1]Ar-Ar ages generalized from Lanphere (1988, 2000), Lipman and others (1996), Lipman (2000), and Bove and others (2001)

LIST OF MAP UNITS

[Some unit exposures on the printed or plotted maps are too small to distinguish the color for unit identification. These units are labeled where possible; unlabeled units are attributed in the database]

SURFICIAL DEPOSITS

- Qal — **Alluvium (Holocene)**
- Qc — **Colluvium (Holocene)**
- Ql — **Landslide deposits (Holocene and Pleistocene)**
- Qf — **Alluvial fan deposits (Holocene)**
- Qt — **Talus (Holocene)**
- Qlo — **Older landslide deposits (Pleistocene)**
- Qfo — **Older alluvial fan deposits (Pleistocene)**

GLACIAL DEPOSITS

- Qr — **Rock glacier (Pleistocene)**
- Qg — **Glacial outwash gravel (Pleistocene; Pinedale glaciation)**
- Qm — **Moraine and till (Pleistocene; Pinedale glaciation)**
- Qmo — **Older moraine and till (Pleistocene; pre-Pinedale glaciation)**
- Qgo — **Older glacial outwash gravel (Pleistocene; pre-Pinedale glaciation)**

POSTCALDERA VOLCANIC ROCKS

Hinsdale Formation (Miocene)

- Thb — **Basaltic flows**
- Thr — **Rhyolite lava, tuff, and intrusion**
- Tha — **Basaltic intrusion**
- Tip — **Los Pinos Formation (Miocene and Oligocene)**

OLIGOCENE VOLCANIC ROCKS

ROCKS OF THE CREEDE CALDERA CYCLE

Creede Formation

- Tc — **Fine-grained sedimentary deposits**
- Tcg — **Conglomerates**
- Tct — **Travertine and calcareous tufa**
- Tcaf — **Dacitic ash-flow tuff**
- Tcl — **Landslide breccia**

Fisher Dacite

- Tfl — **Dacite lava flows**
- Tfb — **Flow breccia**
- Tfa — **Andesitic lava flows**
- Tfv — **Volcaniclastic rocks**
- Tfi — **Intrusions**

Snowshoe Mountain Tuff

- Tsp — **Partly welded tuff**
- Ts — **Densely welded tuff**

Landslide breccia member

Mixed lithologies

- Tslw — **Breccia with clasts of Wason Park Tuff**
- Tslc — **Breccia with clasts of Carpenter Ridge Tuff**
- Tslf — **Breccia with clasts of Fish Canyon Tuff**
- Tslm — **Breccia with clasts of Masonic Park Tuff**
- Tslp — **Breccia with dominant clasts of dacitic lava**
- Tsla — **Breccia with clasts of andesitic lava**

ROCKS OF THE SAN LUIS CALDERA COMPLEX

Rocks of the Nelson Mountain caldera cycle

Baldy Cinco Dacite

Intrusions

- Tbr — **Rhyolite**
- Tbp — **Porphyritic dacite**
- Tba — **Andesite**
- Tbf — **Lava flows**
- Tbv — **Volcaniclastic rocks**

Stewart Peak Volcanics

- Tsi — **Resurgent intrusions**
- Tsp — **Porphyritic dikes and sills**

Mafic dacite

- Tsd — **Lava flows**
- Tsdv — **Volcaniclastic rocks**

Porphyritic to fine-grained andesite

- Tsa — **Lava flows**
- Tsv — **Volcaniclastic rocks**
- Tss — **Tuffaceous sedimentary rocks**

Nelson Mountain Tuff

- Tndn — **Nonwelded to partly welded dacite**
- Tnde — **Welded mafic dacite (Equity facies)**
- Tnd — **Welded silicic dacite and transitional rhyolite-dacite**
- Tnr — **Welded to partly welded rhyolite**
- Tnn — **Nonwelded to partly welded rhyolite and silicic dacite**
- Tnns — **Nonwelded surge-bedded rhyolite**
- Tnxp — **Nonwelded crystal-poor rhyolite**

Landslide breccia lenses

- **Breccia lenses with clasts of Mineral Mountain Rhyolite**
- Tnld — **Breccia lenses with clasts of dacitic lavas**
- Tnlf — **Breccia lenses with clasts of Fish Canyon Tuff**

Rocks of the Cebolla Creek caldera cycle

- Tst — **Tuff and travertine**

Mineral Mountain Rhyolite

- Tmm — **Crystal-poor rhyolite flows and domes**
- Tmmt — **Crystal-poor tuff and tuffaceous sediments**
- Tmmi — **Dacitic-rhyolitic intrusion(?)**
- Tmal — **Local andesitic lava flows**

Dacite of East Willow Creek

- Twl — **Dacite lava**
- Twb — **Carapace breccia**

Cebolla Creek Tuff

- Tccd — **Densely welded mafic dacite**
- Tcc — **Partly welded mafic dacite**
- Tccn — **Nonwelded mafic dacite**

Rocks of the Rat Creek caldera cycle

Mineral Creek Dacite

- Tmix — **Crystal-rich rhyolite lava flows**
- Tmid — **Silicic dacite lava flows**
- Tmt — **Silicic dacite tuff**
- Tmia — **Tuffaceous sediments**

Rat Creek Tuff

- Trdn — **Nonwelded to partly welded dacite tuff**
- Trd — **Welded dacite tuff**
- Trr — **Nonwelded to partly welded rhyolite tuff**
- Trf — **Lithic-rich zone in rhyolite tuff**

Lava flows premonitory(?) to San Luis Caldera complex

Dacite of Captive Inca

- Tcds — **Volcaniclastic sedimentary rocks**
- Tcdf — **Dacite flow**
- Tcdb — **Flow breccia**
- Tcdi — **Vent intrusion**
- Ttd — **Rhyolite of Table Mountain**

Dacite of McKenzie Mountain

- Tmcd — **Dacite flow**
- Tmcb — **Flow Breccia**
- Tmci — **Intrusions**

Dacite of Silver Park

- Tsf2 — **Flow 2**
- Tsf1 — **Flow 1**

Andesite of Bristol Head

- Tbd — **Mafic dacitic flow and breccia**
- Tba — **Andesitic flows**
- Tbav — **Andesitic volcaniclastic rocks**

ROCKS OF THE SOUTH RIVER CALDERA CYCLE

South River Volcanics

- Tsri — **Intrusions**
- Tsrx — **Xenocrystic andesite lava flows**
- Tsrb — **Biotite dacite lava flows**
- Tsrh — **Mafic dacite lava flows**
- Tsra — **Hornblende andesite lava flows**
- Tsrm — **Andesite lava flows**
- Tsrv — **Volcaniclastic rocks**
- Tsrf — **Caldera-wall talus**

Wason Park Tuff

- Twcd — **Intracaldera dacitic tuff**
- Twn — **Nonwelded to partly welded tuff**
- Tw — **Densely welded tuff**

ROCKS OF THE BLUE CREEK CYCLE (caldera concealed)

Lava flows of McClelland Mountain

- Tmd — **Dacite, undivided**
- Tmd2 — **Dacite flow 2**
- Tmd1 — **Dacite flow 1**
- Tma — **Andesite flow**

Blue Creek Tuff

- Tbc — **Densely welded tuff**
- Tbcn — **Nonwelded to partly welded tuff**

Volcanics of Beaver Creek

- Tvbi — **Silicic dacite lava flows**
- Tvbh — **Dacitic lava flows**
- Tvba — **Andesitic lava flows**
- Tvbm — **Andesitic cone breccia**
- Tvbv — **Dacitic volcaniclastic rocks**
- Tvbc — **Andesitic volcaniclastic rocks**
- Tvbs — **Volcanic sedimentary rocks**

ROCKS OF THE BACHELOR CALDERA CYCLE

Dacite of Shallow Creek

- Tscf — **Flow and flow breccia**
- Tsci — **Intrusion**
- Tbs — **Intracaldera sedimentary rocks**

Carpenter Ridge Tuff

Outflow tuff units

- Tcm — **Mammoth Mountain Member**
- Tcrf — **Mafic fiamme zone**
- Tcr — **Outflow rhyolite tuff**

Intracaldera units

Intracaldera Bachelor Mountain Member

- Tcbz — **Rheomorphic and intrusive tuff unit**
- Tcbg — **Windy Gulch welding zone**

Campbell Mountain welding zone

- Tcbc — **Least altered tuff**
- Tcbck — **Potassium-metasomatized tuff**
- Tcbw — **Willow Creek welding zone**
- Tcbp — **Shallow Creek Breccia Member**
- Tcsb — **Andesitic breccia member**
- Tcwb — **Wagon Wheel Gap Breccia Member**

Phoenix Park Breccia Member

- Tcpt — **Landslide-breccia unit**
- Tcpl — **Talus-breccia unit**
- Tmr — **Rhyolite of Miners Creek**

ROCKS ERUPTED FROM THE SILVERTON CALDERA (western San Juan Mountains)

- Tcll — **Crystal Lake Tuff**

ROCKS OF LA GARITA CALDERA CYCLE

Huerto Andesite

- Thu — **Andesitic lava flows and volcaniclastic rocks, undivided**

Intrusions and vents

- Thd — **Dacite**
- Tha — **Andesitic dikes and other intrusions**
- Thap — **Porphyritic andesitic dikes and other intrusions**
- Thai — **Intrusions of hornblende andesite and mafic dacite**

Lava flows

- Thd — **Dacite**
- Tha — **Finely porphyritic and undivided andesite**
- Thah — **Hornblende-bearing andesite-dacite**
- Thap — **Platy plagioclase andesite**
- Thv — **Vent scoria**

Volcaniclastic rocks

- Thv — **Bedded breccia and conglomerate**
- Thlf — **Landslide breccia with clasts of Fish Canyon Tuff**
- Thlp — **Landslide breccia with clasts of Pagosa Peak Dacite**
- Thc — **Conglomerate and sandstone with clasts of Fish Canyon Tuff**
- Tgs — **Intracaldera sedimentary rocks**
- Thtd — **Dacite of Nutras Creek**

Fish Canyon Tuff

- Tgfi — **Late intracaldera landslide breccia**
- Tfc — **Outflow tuff sheet**—Local welding zones Tfc1, Tfc2, Tfc3, Tfc4, Tfc5, Tfc6
- Tfg — **La Garita Member**
- Tfgi — **Lithic-rich partly welded zone**
- Tgfd — **Intracaldera landslide breccia with clasts of Fish Canyon Tuff**
- Tgfp — **Intracaldera landslide breccia with clasts of Pagosa Peak Dacite**
- Tgfm — **Intracaldera landslide breccia with clasts of Masonic Park Tuff**
- Tgfs — **Intracaldera landslide breccia with clasts of Sheep Mountain Andesite**
- Tgfw — **Intracaldera landslide breccia with clasts of western San Juan tuff sheets**

Pagosa Peak Dacite

- Tpl — **Massive lava-like rocks**
- Tpc — **Carapace breccia**
- Tpr — **Rheomorphically brecciated zone**
- Tpbb — **Pyroclastic breccia**
- Tpsl — **Lens of andesitic slide breccia**
- Tpb — **Blob-and-ash deposits**
- Tpbl — **Lithic-bearing blob-and-ash deposits**
- Tpp — **Pyroclastic-flow deposits**

ROCKS ERUPTED FROM THE PLATORO CALDERA COMPLEX

Treasure Mountain Group

- Ttc — **Chiquito Peak Tuff**

ROCKS OF THE MASONIC PARK CYCLE (caldera concealed)

Sheep Mountain Andesite

- Tsma — **Porphyritic andesite**
- Tsmd — **Hornblende dacite**
- Tsmv — **Volcaniclastic rocks**
- Tmp — **Masonic Park Tuff**—Local welding zones Tmp1, Tmp2, Tmp3, Tmp4
- Tmpl — **Lower welding zone**
- Tmpb — **Brecciated tuff**

OLDER ROCKS RELATED TO WESTERN SAN JUAN CALDERAS

- TsM1 — **Tertiary landslide breccia**

Silverton Volcanics(?)

- Tsvl — **Andesitic lavas and breccias**
- Tsvv — **Volcaniclastic rocks**

Western San Juan tuff sheets

- Tws — **Sapinero Mesa Tuff**
- Twd — **Dillon Mesa Tuff**
- Twb — **Blue Mesa Tuff**
- Twu — **Ute Ridge Tuff**
- Twa — **Local andesitic lava flow**

ROCKS ERUPTED FROM THE PLATORO CALDERA COMPLEX

Lower member of Summitville Andesite

- Tsua — **Andesitic lava flows**
- Tsup — **Porphyritic andesite flows**
- Tsuv — **Volcaniclastic rocks**

Treasure Mountain Group

- Tt — **Treasure Mountain Group, undivided**
- Tts — **South Fork Tuff**
- Ttr — **Ra Jadero Tuff**
- Ttm — **Middle tuff**
- Ttj — **La Jara Canyon Tuff**
- Ttb — **Black Mountain Tuff**
- Ttl — **Lower rhyolite tuff**

ROCKS PREDATING CENTRAL CALDERA CLUSTER

Tuff of Luders Creek

- Ttd — **Welded dacite**
- Ttn — **Nonwelded to partly welded rhyolite**

Tuff of Saguache Creek

- Tscc — **Densely welded crystal-rich rhyolite**
- Tsc — **Nonwelded to densely welded crystal-poor rhyolite**

Conejos Formation

- Tci — **Intrusions**

Lava flows and proximal breccias

- Tcf — **Lava flows and breccias, undivided**
- Tca — **Andesite**
- Tcap — **Porphyritic andesite**
- Tcd — **Dacite**
- Tcr — **Rhyolite**
- Tcv — **Volcaniclastic rocks**
- Tcs — **Volcanic sandstone**
- Tcas — **Arkosic sandstone**
- Tcst — **Tuff of Snowball Park**

Intrusions of uncertain affinity

- Tia — **Andesite**
- Tid — **Dacite**

PREVOLCANIC ROCKS

- Tbb — **Blanco Basin Formation (Eocene)**
- Ku — **Sedimentary rocks, undivided (Cretaceous)**
- pЄq — **Quartzite (Precambrian)**

Contact—Dashed where approximately located; dotted where gradational. Internal contacts delineate some conspicuous lava flows or gradational ash-flow cooling breaks within map units. No contact shown where boundary between map units is uncertain or indefinite

Concealed intrusive contact

Lava-flow vent boundary

Fault—Dashed where approximately located; dotted where concealed or occupied by intrusive rocks. Bar and ball on downthrown side

Ramp structure—Sawteeth on upper side. Near tops of lava flows, domes, and lava-like parts of Pagosa Peak Dacite

Quaternary slump block—Approximately located; hachures on downthrown side

Hinge line—Dashed where approximately located; dotted where concealed. Marks north margin of resurgence within San Luis caldera complex. Double hachures indicate direction of uplift

Unconformity along caldera wall—Dashed where approximately located; dotted where concealed. Listed younger to older

- **Creede**

San Luis Complex

- **Nelson Mountain and Cochetopa**
- **Cebolla Creek**
- **Rat Creek**
- **South River**
- **Bachelor**
- **La Garita**

Depositional synclinal sag—In east moat of La Garita caldera (sheet 1)

Strike and dip of beds

- 30 **Inclined**
- **Horizontal**

Strike and dip of foliation

- 40 **Inclined**
- **Horizontal**
- **Vertical**

Lineation—Showing bearing and plunge. Defined by elongate pumice lenses or flow structures. May be combined with foliation symbol

Hydrothermally altered rock—Areas of conspicuous supergene acid-sulfate alteration, mainly due to dissolution of pyrite, in vicinity of subvolcanic intrusions

Age determination—In Ma (table 1). Mostly $^{40}Ar/^{39}Ar$ (s, sanidine; b, biotite; p, plagioclase; h, hornblende), a few K-Ar whole rock (w)

Drill site—Creede Continental Scientific Drilling Program

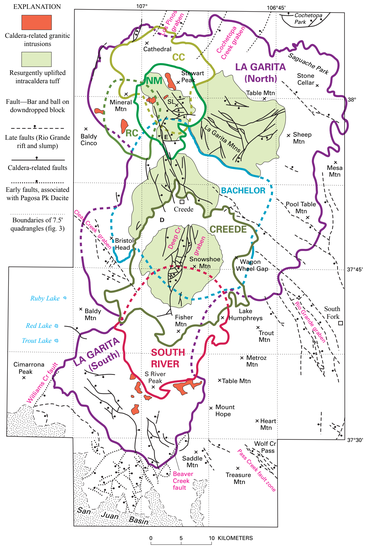


Figure 6. Granitic intrusions (texturally variable granodiorite-andesite) and regional caldera-related and other faults, in relation to overall geometry of central San Juan caldera cluster. E, Equity block (fault-bounded triangular uplift). Abbreviated geographic name: SL, San Luis Peak. Calderas of San Luis complex: CC, Cebolla Creek; NM, Nelson Mountain; RC, Rat Creek.

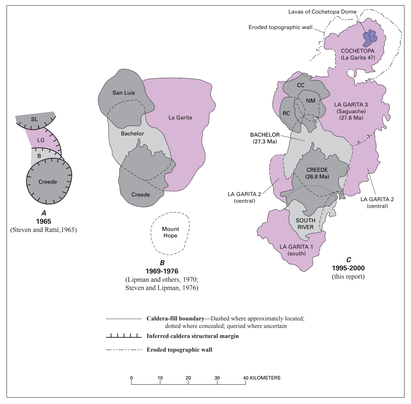


Figure 4. Maps showing successive interpretations (1965-2000) of central San Juan caldera geometry: B, Bachelor; CC, Cebolla Creek; LG, La Garita; NM, Nelson Mountain; RC, Rat Creek; SL, San Luis. *A*. Initial caldera identifications. *B*. Revised geometries. *C*. Present interpretation.

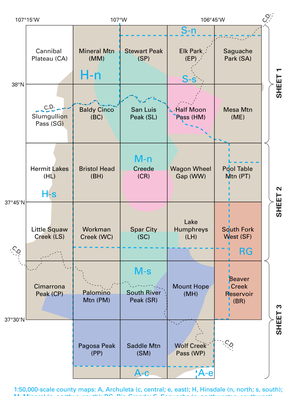
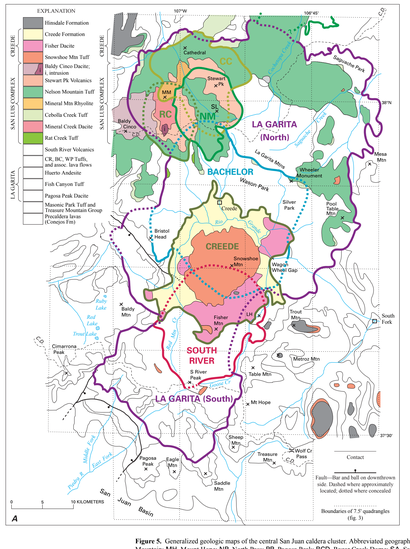
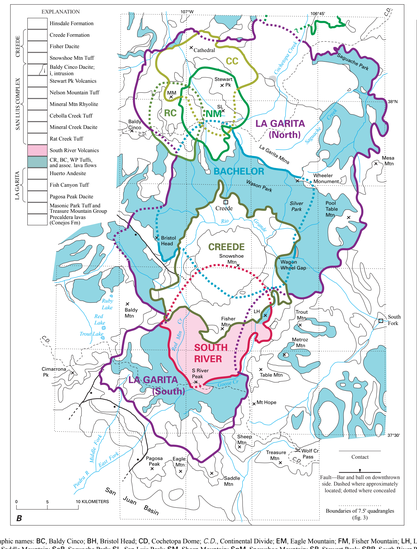


Figure 3. Map of central cebolla cluster, showing areas of geologic mapping responsibilities, 7.5' topographic quadrangles (black lines; abbreviations used on maps and in text for files in database), and 1:50,000-scale county maps (blue dashed lines; used as base for printed maps). C.D., Continental Divide.





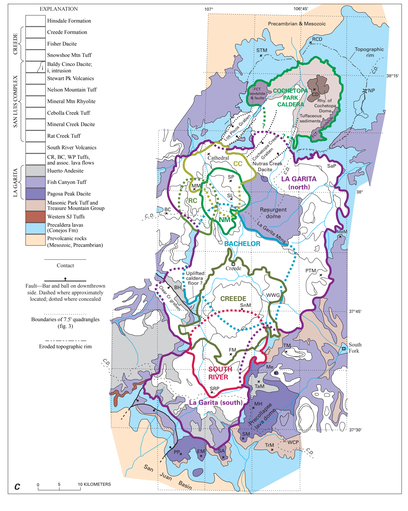


Figure 5. Generalized geologic maps of the central San Juan caldera cluster. Abbreviated geographic names: **BC**, Baldy Cinco; **BH**, Bristol Head; **CD**, Cochetopa Dome; *C.D.*, Continental Divide; **EM**, Eagle Mountain; **FM**, Fisher Mountain; **LH**, Lake Humphreys; **MM**, Mineral Mountain; **Me**, Metroz Mountain; **MeM**, Mesa Mountain; **MH**, Mount Hope; **NP**, North Pass; **PP**, Pagosa Peak; **RCD**, Razor Creek Dome; **SA**, Saddle Mountain; **SaP**, Saguache Park; **SL**, San Luis Peak; **SM**, Sheep Mountain; **SnM**, Snowshoe Mountain; **SP**, Stewart Peak; **SRP**, South River Peak; **STM**, Sawtooth Mountain; **TaM**, Table Mountain; **TM**, Trout Mountain; **TrM**, Treasure Mountain; **WCP**, Wolf Creek Pass; **WWG**, Wagon Wheel Gap. Calderas of San Luis complex: **CC**, Cebolla Creek; **NM**, Nelson Mountain; **RC**, Rat Creek. Ash-flow sheets: **BC**, Blue Creek Tuff; **CR**, Carpenter Ridge Tuff; **WP**, Wason Park Tuff. ***A***. Geometry of the San Luis caldera complex, Creede caldera, and associated ash-flow sheets. ***B***. Geometry of the Bachelor caldera, South River caldera, and associated ash-flow sheets. ***C***. Geology of La Garita caldera and associated proximal eruptive deposits. **FCT**, Fish Canyon Tuff; **SJ**, San Juan.

Geologic Map of the Central San Juan Caldera Cluster, Southwestern Colorado

By
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2006

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