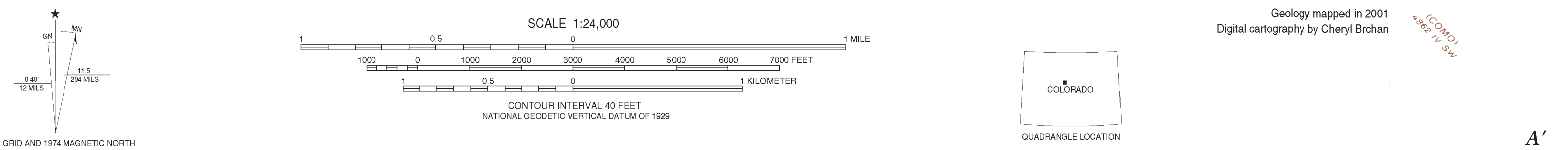
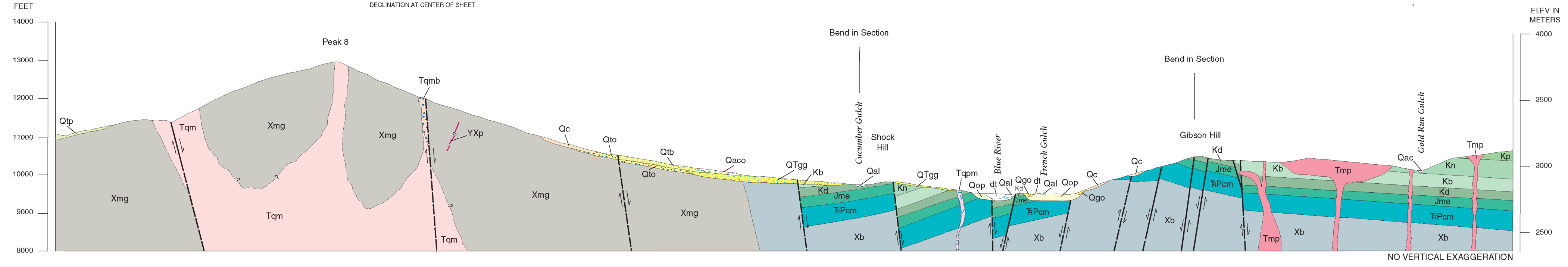
COLORADO GEOLOGICAL SURVEY
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

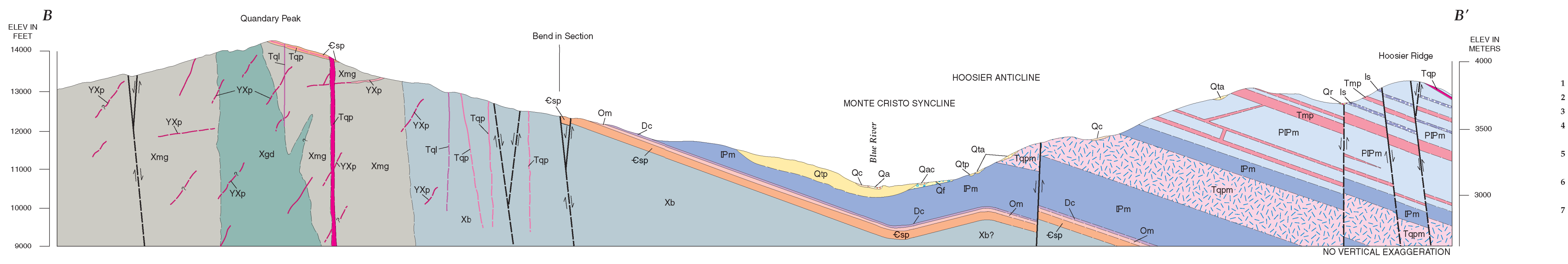
OPEN-FILE MAP 02-7
GEOLOGIC MAP OF THE BRECKENRIDGE QUADRANGLE
SUMMIT AND PARK COUNTIES, COLORADO
Booklet accompanies map

Base from U.S. Geological Survey, 1987
Polyconic projection, 1927 North American datum
10,000-foot grid based on Colorado coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

Geology mapped in 2001
Digital cartography by Cheryl Brchan







DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af — **Artificial fill (Recent)**—Compacted and noncompacted gravel and finer material underlying road beds and embankments along Colorado Highway 9. Largest fill areas in reworked Pinedale till. Also includes material of earthfill dams at Goose Pasture Tarn and upper Blue Lake in Monte Cristo Valley

dt — **Dredge tailings (Recent)**—Nonconsolidated, clast-supported deposits containing mostly well-rounded to subrounded, cobble- to boulder-size clasts derived from placer mining in Blue River and French Gulch. Dredge tailings mapped from 1968 air photos

ht — **Hydraulic tailings (Recent)**—Mounds and small piles of typically well-rounded to subrounded cobbles and boulders in areas of gold-bearing gravel deposits that were hydraulically mined during the early days of mining

mw — **Mine waste (Recent)**—Compacted and noncompacted rock fragments and finer material generated by bedrock (lode) mining and processing. Includes coarse rock waste excavated from mine shafts and tunnels, and finer crushed rock waste (tailings) deposited in settling ponds

Qlsh — **Historic landslide deposits (Recent)**—Chaotically arranged debris with hummocky surface. Easily identifiable source and living vegetation on slide mass. Historic age confirmed by disruption of cultural features. Mapped only at Aqueduct Road south of Monte Cristo Gulch. Maximum thickness about 5 m

Qal — **Alluvium (Holocene)**—Nonconsolidated, clast-supported deposits of silt- to boulder-size, moderately sorted to well sorted clasts in modern floodplains; includes finer-grained overbank deposits. Clasts are as long as 1 m in Blue River channel, and larger in some steeper tributary channels. Includes small areas of wetland deposits in, and adjacent to Cucumber Gulch, Indiana Creek, and Pennsylvania Creek. Maximum thickness probably less than 5 m

Qf — **Fan deposits, undivided (Holocene and late Pleistocene)**—Moderately sorted sand- to boulder-size gravel in fan-shaped deposits from tributary streams to the Blue River, and from smaller side streams to those tributaries. Deposits typically composed of both matrix-supported beds 1- to 1.5-m thick (debris flow facies) and clast-supported beds 0.3-to 0.8-m thick (streamflow facies). These facies are commonly interbedded. Clasts mostly subangular to subround. Maximum thickness may be 30 m in larger fans

Qfy — **Younger fan deposits (late Holocene)**—Same as map unit Qf, but most recent phase of deposition is adjacent to modern stream channels

Qfi — **Fan deposits of intermediate age (middle Holocene to late Pleistocene)**—Same as map unit Qf, but older postglacial fans not near the locus of modern deposition. Modern channel is typically incised several meters into these deposits

Qtn — **Neoglacial till (late to middle Holocene)**—Nonsorted and nonstratified bouldery till in cirque moraines. Subangular to subround clasts composed mainly of Proterozoic gneiss and plutonic rocks. Soil profile is very thin and boulders are not weathered. Occurs in Crystal Creek, Spruce Creek, and McCullough Gulch. As thick as 15 m

Qtf — **Talus fan deposits (Holocene)**—Angular and subangular, sand- to boulder-size rock fragments below cliffs. Distinguished from talus (Qta and Qti) by steep, fan-shaped morphology and presence of a channel with debris-flow levees. Maximum thickness not known but could be as thick as 30 m based on morphology

Qti — **Inactive talus deposits (Holocene and late Pleistocene)**—Same as map unit Qta, but partly to completely stabilized by grass and tree cover. Contains some sandy matrix at surface

Qs — **Solifluction deposits (Holocene and late Pleistocene)**—Nonconsolidated, silt- to boulder-size rock debris located on gentle to moderate slopes above treeline in the Tenmile Range and on Red Mountain. Generally matrix-supported, but contains pockets of angular, cobble- to boulder-size clasts with no matrix (small blockfields, or felsenmeer). Commonly contains springs and ponds, suggesting discontinuous permafrost conditions. Includes both active deposits subject to downslope creep from frost heaving, and inactive deposits above the Pinedale glacial limit. Maximum thickness probably 3 to 5 m

Qpr — **Protalus rampart deposits (Holocene)**—Similar to active talus (Qta), except clast size is larger and deposit forms a bench or slope-parallel ridge at the base of a talus slope

Qta — **Active talus deposits (Holocene)**—Angular to subangular, cobble- to boulder-size rock fragments on steep mountain sides and below cliffs. Boulders generally as large as 2 m. Sandy matrix is rarely exposed at surface. Talus grades into areas of frost-shattered bedrock which are mapped as underlying bedrock unit. Maximum thickness probably about 20 m

Qra — **Active rock glacier deposits (late Holocene)**—Hummocky, lobate deposits of mostly angular boulders having a frontal slope at the angle of repose. Deposits are ice-cored and moving slowly downslope; boulders on frontal slope are not covered with lichen and the internal sandy matrix is exposed. Mapped only at the head of Spruce Creek. Maximum thickness about 40 m

Qr — **Inactive rock glacier deposits (early to middle Holocene)**—Hummocky, lobate deposits of mostly angular boulders having a frontal slope below the angle of repose. Boulders on top, sides, and front are covered with lichen, so deposits are inferred to be stationary. Includes lobate rock glaciers along valley side slopes. Also includes tongue-shaped rock glaciers in cirque heads, inferred to possess solid ice cores from Neoglacial glaciers buried by talus. Maximum thickness about 50 m

Qls — **Landslide deposits, undivided (Holocene to middle Pleistocene)**—Range from chaotically arranged debris to nearly intact blocks of bedrock. Surface of deposits commonly hummocky, and source area of landslide is generally identifiable (top of scarp area indicated by thick dashed lines with ticks in direction of slide). Large landslide deposits greater than 50 m thick

Qlsy — **Younger landslide deposits (late Holocene)**—Chaotically arranged debris with hummocky surface and easily identifiable source area. Recent age inferred from sharpness of the hummocky topography, presence of closed depressions, and non-vegetated headscarp

Qlsi — **Intermediate-age landslide deposits (middle Holocene to late Pleistocene)**—Similar to map unit Qlsy, but older; postglacial landslides typically covered by forest

Qlsc — **Landslide complex (Holocene and late Pleistocene)**—Area of many landslides of several types interspersed with stable areas that are too small to map. Includes small slumps, debris flows, and earthflows of different ages. Shown only on the northwest slope of Mount Argentine

Qlso — **Older landslide deposits (late to middle Pleistocene)**—Similar to map unit Qlsy, but older than Pinedale glaciation (23 ka). Deposits are generally large masses of almost intact bedrock that slid off glaciated valley walls and cirque walls in the Tenmile Range; the allochthonous masses of bedrock were subsequently smoothed and eroded by Pinedale glaciers

Qc — **Colluvium (Holocene and late Pleistocene)**—Nonconsolidated to slightly indurated, mostly massive, dark-brown to light-gray-brown deposits that mantle gentle to moderate hillslopes. Rock clasts and fine-grained material mixed by downslope movement. Generally matrix supported, but may contain angular fragments of locally derived bedrock up to boulder size. Locally overlain by loess, eolian silt, and fine sand with a poorly to moderately developed soil profile. Generally unsorted and nonstratified but may contain thin lenses of fine gravel deposited by sheetwash and small debris flows. Commonly underlies lower parts of hillslopes. Grades laterally into residuum developed on local bedrock. Small areas of colluvium not shown on map where the deposits are thinner than 2 m or discontinuous. Maximum thickness about 5 m

Qrf — **Rockfall deposits (Holocene)**—Very large, angular blocks of bedrock derived from a single catastrophic rockslide or rockfall avalanche (after terminology of Cruden and Varnes, 1996). Mapped only in McCullough Gulch and Spruce Creek. Maximum thickness about 30 m

Ql — **Lacustrine deposits (Holocene and late Pleistocene)**—Sand, silt, and clay deposited in lakes. Overlain by dark-brown to black, organic-rich sediment in wetland areas; typified by standing water, beaver ponds, and dense willow stands. Surface organic sediment may be interbedded with thin, sandy alluvium. Maximum thickness of organic sediment less than 3 m, but over much thicker lake deposits upstream from Goose Pasture Tarn in the Blue River Valley. Maximum thickness up to 30 m in Blue River Valley, but thinner (5 to 10 m) in smaller lake basins in tributaries

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Alluvium composed of unconsolidated silt- to boulder-size, moderately to well-sorted sediment in ephemeral and intermittent tributary streams and swales. Generally includes alluvium in valley axis and colluvium on valley sidewalls where deposits are too small to show separately. Colluvium may contain loess. Maximum thickness about 10 m

Qfp — **Fan deposits of Pinedale glaciation (late Pleistocene)**—Moderately well-sorted sand to boulder gravel in fan-shaped deposits that emanate from Pinedale moraines. Contain boulders up to 4 m in diameter and grade into moraines. Maximum thickness about 10 m

Qop — **Pinedale outwash deposits (late Pleistocene)**—Moderately well-sorted sand to boulder gravel that forms outwash terraces that grade to Pinedale terminal moraines. Pinedale outwash deposits form most of the floor of Blue River Valley between Breckenridge and the northern boundary of map area. Terrace surface lies 3–5 m above modern stream. Deposit extensively placer mined and dredged. Maximum thickness is 27 m between Breckenridge and the Pinedale terminal moraine, and the thickness is 15 to 18 m downstream from Breckenridge (Ransome, 1911, p. 78). In lower French Gulch maximum thickness is 13 to 15 m. Thicknesses are total depths to bedrock and may include some underlying pre-Pinedale alluvium

Qop_2 — **Pinedale outwash deposits of intermediate age (late Pleistocene)**—Similar to map unit Qop but differentiated only in downtown Breckenridge. Forms a broad terrace west of Blue River, much of which has been buried by tributary fans (Qf) from Sawmill Gulch and the next unnamed tributary to the north. Also underlies Breckenridge east of the Blue River and west of Main Street. Terraces are 2 to 3 m above the modern Blue River. Terrace is not physically connected with intermediate-age Pinedale moraine (Qtp_2), so the terrace may be partly correlative with younger Pinedale moraines (Qtp_3). Maximum thickness at least 3 m

Qop_1 — **Older Pinedale outwash deposits (late Pleistocene)**— Similar to map unit Qop but differentiated only in downtown Breckenridge east of the Blue River. Traced southward, this terrace grades into the older Pinedale terminal moraine (Qtp_1) on the southern margin of Breckenridge. Forms a narrow terrace 5 m above modern Blue River, between Main Street and Ridge Street, and a terrace remnant at Highway 9 and Boreas Pass Road. Maximum thickness at least 5 m

Qtp — **Till of Pinedale glaciation, undivided (late Pleistocene)**—Unsorted and unstratified bouldery till in moraines that have preserved original hummocky topography, commonly containing closed depressions and small ponds. In Blue River Valley, subround to subangular clasts are composed mainly of Proterozoic crystalline rocks with a smaller percentage of clasts of lower Paleozoic quartzite. In Indiana and Pennsylvania Creeks, subround to subangular clasts are composed of Maroon Formation, Dakota Sandstone, and Tertiary porphyry. Also forms a complex of coalescing moraine lobes on forested piedmont between Peaks 6 and 7 and Blue River. Soil profile generally thin with little clay development, and boulders are not weathered. Locally contains minor outwash, colluvium, and lacustrine deposits. Age of Pinedale deposits at the type area in Wyoming is 16–23 ka (Chadwick and others, 1997). Thickness may exceed 100 m

Qtp_3 — **Younger till of Pinedale glaciation (latest Pleistocene)**—Poorly to moderately sorted and poorly to moderately stratified sand and gravel in moraines that show fresh constructional topography. Forms the youngest recessional moraine of Blue River glacier that impounds Goose Pasture Tarn. Along Highway 9 most of recessional moraine is composed of silt and sand beds that dip south at 10 degrees. The beds probably represent older Pinedale lake deposits that were "bulldozed" into the recessional ridge by the final ice advance. Till on western valley wall is a bouldery diamicton that contains abundant clasts of Proterozoic gneiss. Thickness of recessional moraine is about 30 m

Qtp_2 — **Intermediate-age till of Pinedale glaciation (late Pleistocene)**—Poorly to moderately sorted and poorly to moderately stratified sand and gravel in moraines with fresh constructional topography. Forms a thin belt of lateral moraines west of Goose Pasture Tarn. Maximum thickness probably 25 m

Qtp_1 — **Older till of Pinedale glaciation (late Pleistocene)**—Nonsorted and nonstratified boulder gravel in moraines that show fresh constructional topography. Contains subrounded clasts of Proterozoic crystalline rocks up to 4 m in diameter in a light-gray matrix of sand and silt. Forms terminal moraine of the Pinedale glaciation in south Breckenridge between Illinois Gulch and Blue River. Thickness about 30 m

Qob — **Bull Lake outwash deposits (middle Pleistocene)**—Moderately well-sorted sand to boulder gravel that comprises outwash terraces graded to Bull Lake terminal moraine. Terrace surface lies 12 to 14 m above stream level and underlies eastern half of the Town of Breckenridge. May also underlie extensive areas of Pinedale outwash in Blue River Valley. Thickness probably ranges between 12 and 18 m

Qfb — **Bull Lake alluvial fan (middle Pleistocene)**—Moderately well-sorted sand to boulder gravel in fan-shaped deposits. Mapped only between Sawmill Gulch and Cucumber Gulch, where fan lies adjacent to, but outside, the Bull Lake moraine and laps onto the QTgg surface

Qtb — **Till of Bull Lake glaciation (middle Pleistocene)**—Poorly sorted and poorly stratified bouldery till in moraines with subdued surface morphology. Forms a pair of eroded ridges in south Breckenridge, remnants of Bull Lake terminal moraine that extended just north of Illinois Gulch. Forms a fringe to coalescing Pinedale moraine lobes on forested piedmont between Peaks 6 and 7 and the Blue River. Subrounded to subangular clasts mostly of Proterozoic gneiss. Distinguished from Pinedale till by its broader, smoother moraine crests, gentler slope angles, fewer surface boulders, oxidized (orange) matrix color, and presence of occasional decomposed clasts. Soil profile moderately developed and contains a clayey texture B horizon. Maximum thickness about 30 m

Qto — **Older till, undifferentiated (middle to early Pleistocene)**—Poorly sorted and poorly stratified bouldery till in moraines that have subdued surface morphology. Mapped in areas where relation to younger Pinedale till is obscure, or on steep slopes where moraine morphology is indistinct. May include till of Bull Lake or pre-Bull Lake age. As thick as 60 m in Cucumber Creek area

Qao — **Older alluvium, undifferentiated (middle to early Pleistocene)**—Moderately sorted and stratified, locally derived stream deposits in tributaries to Blue River. Finer grained than unit Qgo deposited by the ancestral Blue River. Incised by younger streams by 10 m of down-cutting. Older alluvial surfaces no longer receive alluvial deposits, although upslope parts may receive thin sheetwash deposits from adjacent hillslopes. Shown in upper Illinois Gulch and between Lehman and Sawmill Gulches in Breckenridge Ski Area. Maximum thickness about 10 to 15 m

Qaco — **Older alluvium and colluvium (middle and early Pleistocene)**—Moderately to poorly sorted and stratified gravelly sand and sandy gravel deposited by rillwash, sheetwash, and creep. Grades downslope into older alluvial units Qfb, Qao, or Qtgg. Maximum thickness probably less than 10

Qgo — **Older gravels (middle to early Pleistocene)**—Moderately well-sorted sand to boulder gravel that forms high-level, dissected terraces in the Blue River Valley north of Bull Lake terminal moraine. East of Blue River forms a terrace 36 m above modern stream level. Contains a well-developed soil profile and weathered clasts are common. May be glacial outwash of pre-Bull Lake age. Maximum thickness probably 20 m

QTgg — **Gravel of Gold Run (early Pleistocene and late Pliocene)**—Poorly to well sorted, massive to well-stratified, poorly to moderately consolidated, grayish-orange sand and gravel. Underlies high-level terrace remnants (60- to 115-m above stream level) in Blue River Valley downstream from terminal moraines. Includes two facies: (1) older Blue River alluvium; and, (2) younger (or coeval) alluvium and colluvium from tributaries. Blue River alluvium is well-stratified sand and rounded to subrounded cobble gravel derived from Proterozoic crystalline rocks, and this alluvium underlies terraces west of Blue River between Sawmill Gulch and northern map boundary. Contains a thick, red soil profile; many clasts are decomposed. Tributary alluvium and colluvium underlie the southern slopes of French Gulch north of Barney Ford Hill between about 9,700 and 9,880 ft. elevation (as much as 55 m above French Gulch) and alluvium forms slopes northeast of Gibson Hill. Alluvium generally massive to poorly stratified gravelly sand, with angular cobbles and pebbles floating in sandy clay matrix. Capped by a strong red soil greater than 2 m thick

BEDROCK

Tql — **Quartz latite porphyry (Eocene?)**—Very light-gray, grayish-tan, and light-grayish-white, fine-grained, porphyritic, quartz latite dikes. Phenocrysts of quartz, plagioclase, and potassic feldspar (sanidine?) are 1 to 2 mm long, and rare biotite phenocrysts are altered to fine-grained muscovite, chlorite, and iron oxide. Phenocrysts comprise 5 to 20 percent of the rock. Quartz phenocrysts are rounded and show partial resorption. Groundmass is dense and sometimes flinty. Occurs only near Quandary Peak in southern part of Tenmile Range

Tqmb — **Quartz monzonite intrusion breccia (middle Eocene)**—Angular to sub-angular clasts of country rock up to 60 cm in diameter in a matrix of fine- to medium-grained, light-gray to light-tan quartz monzonite similar to that of the Humbug Stock. Clasts consist mostly of Proterozoic gneiss

Tqm — **Quartz monzonite of the Humbug stock (middle (Eocene)**—Humbug Stock and smaller outlying intrusives. White to very light-gray to light-tan-orange, medium- to coarse-grained, phaneritic quartz monzonite. Hypidiomorphic-granular texture. Consists principally of quartz (20 percent), oligoclase-andesine (40 percent), microcline microperthite (35 percent), and biotite (5 percent). Hornblende and magnetite are minor constituents. Euhedral biotite gives the rock a black-mottled appearance. A new $^{40}Ar/^{39}Ar$ age date from sample K01-059 on Peak 9 indicates an age of 42.05 ± 0.23 Ma for the Humbug stock

Tqpm — **Quartz monzonite porphyry-megacrystic variety (Eocene)** —Buff to light-brown weathering, porphyritic, quartz-plagioclase-orthoclase-biotite-hornblende quartz monzonite that contains prominent large phenocrysts (megacrysts) of orthoclase, quartz, and plagioclase. Orthoclase megacrysts are typically 2- to 4-cm in length and compose as much as 20 percent of the rock. Quartz phenocrysts (commonly partially resorbed and embayed) compose 2 to 10 percent of the rock. Euhedral biotite forms 1 to 3 percent of the rock and biotite is much more abundant than sparse hornblende. The groundmass is fine grained (<0.5 mm). Similar quartz monzonite porphyry from a large intrusive mass in the Frisco quadrangle to the north of Breckenridge yielded a potassium-argon date from biotite of 44.1 ± 1.6 Ma (Marvin and others, 1989)

Tqp — **Quartz monzonite porphyry (Eocene)**—Grayish-tan to light-brown weathering, porphyritic, quartz-plagioclase-orthoclase-biotite-hornblende quartz monzonite. Quartz monzonite porphyry is mapped as small masses and dikes in the southern part of the quadrangle and in the Rocky Point area. Feldspar phenocrysts (orthoclase and plagioclase) typically compose 10 to 25 percent of the rock and quartz phenocrysts compose 2 to 8 percent of the rock. Typical quartz and feldspar phenocryst size is 2 to 6 mm. Euhedral biotite phenocrysts up to 3 mm long forms 2 to 10 percent of the rock and biotite is much more abundant than rare hornblende. The groundmass is fine grained (<0.5 mm). The quartz monzonite porphyry that contains megacrysts (Tqpm) crosscuts the quartz monzonite porphyry without megacrysts (Tqp)

Tmp — **Hornblende-biotite monzonite porphyry (Eocene)**—Dark-gray porphyry contains 5 percent plagioclase phenocrysts that are 1 to 3 mm long, 5 percent orthoclase phenocrysts that are 1- to 3-mm long, 3 percent hornblende that form subhedral blades 1 to 6 mm long, and 3 percent biotite that forms pseudohexagonal phenocrysts that are 1 to 2 mm wide. Groundmass is aphanitic. Occurs as sills and dikes and as a large intrusive mass in the northeastern corner of the quadrangle. The monzonite porphyry is intruded by megacrystic quartz monzonite porphyry (Tqpm), although both phases are considered close in age (Ransome, 1911; Lovering, 1934)

Kp — **Pierre Shale (Late Cretaceous)**—Dark-gray, brownish-gray, and black marine shale and mudstone. Lowest 10- to 20-m is calcareous, and calcite veins are common near basal contact. In weathered outcrops, bedding fissility is visible. Conformable, gradational lower contact with underlying Niobrara Formation Approximately 400 m thick

Kn — **Niobrara Formation (Late Cretaceous)**—Consists of two members that were not mapped separately. Conformable above Benton Shale

Smoky Hill Shale Member—Gray and light-gray, platy-weathering, calcareous shale and shaly limestone. Becomes more shaly upward. Thickness 138 m in region

Fort Hays Limestone Member—Blocky, gray, light-gray weathering, resistant-weathering micritic limestone in beds 5- to 15-cm thick. Commonly contains encrusted Inoceramids (oysters). About 6- to 10-m thick

Kb — **Benton Shale (Late Cretaceous)**—Uppermost 1.5 m is a thin-bedded, black to dark-gray, fetid, resistant-weathering, crystalline limestone that shows pinch-and-swell structures and contains thin, dark-gray, siliceous siltstone interbeds. Uppermost limestone overlies 5 m of dark-gray, fetid limestone and dark-brown to gray calcareous, rusty siltstone and shale which, in turn, overlies about 3 m of resistant brownish-gray, fine-grained, rusty, arkosic sandstone that is bioturbated at base and locally contains chert pebbles. Sandstone unconformably overlies 85 to 100 m of mostly dark-brown to black, fissile, rusty shale. Lowermost 25 m of this shale consists of wavy-bedded black shale that contains fish scales. Basal 3 m consists of fine-grained, gray quartzite beds. Benton Shale is 95- to 110-m thick. Conformable above Dakota Group

Kd — **Dakota Sandstone (Early Cretaceous)**—Three informal members combined on map

Upper quartzite member—Light-gray, commonly cross-bedded quartz sandstone. Contains ripple marks, worm tubes, leaf and branch casts. Rare rare, thin, black, commonly carbonaceous, shale interbeds. Base is massive-weathering resistant-weathering quartzitic sandstone bed that is 2-m thick. Joint surfaces are stained with limonite. About 10-m thick

Middle black shale member—Interbedded gray to black, locally carbonaceous shale and generally thin- to medium- bedded, medium-grained, gray to light-gray quartz sandstone. Beds as thick as 2 m. About 18 m thick

Lower quartzite member—Massive, medium-to fine-grained, grayish-white, subrounded, poorly sorted quartz sandstone with thin, dark-gray shale interbeds. Sandstone is commonly rusty on joint surfaces. About 29- to 34-m thick. Unconformable above Morrison Formation

Jme — **Morrison Formation and Entrada Sandstone, undivided (Late Jurassic)**—Combined on cross section A–A'

Jm — **Morrison Formation (Late Jurassic)**—Light-gray and light-greenish-gray, locally calcareous claystone. Upper 17 m weathers as thin chips of red and green siltstone and shale. Lower half of formation contains several light-yellow to white, medium-grained sandstone beds as thick as 5 m. Sandstone commonly contains limonitic spots and rusty bands parallel to joint surfaces. A prominent 2- to 4-m-thick gray limestone bed occurs 5 to 10 m above base. Morrison Formation conformably overlies Entrada Sandstone. About 85 m thick

Je — **Entrada Sandstone (Middle Jurassic)**—Light-gray to pale-yellowish-gray, well-sorted, fine- to medium-grained, commonly crossbedded, carbonate-cemented, quartz sandstone. Grains are frosted, reflecting eolian deposition. Small, brown limonitic spots are common. Thickness is 5 to 11 m Unconformably overlies Triassic–Pennsylvanian red beds

TRPcm — **Chinle Formation (Late Triassic) and Maroon Formation, undivided (Late Pennsylvanian and Early Permian)**—Bright grayish-orange and reddish-orange, calcareous shale, siltstone, and fine-grained sandstone of the Chinle Formation overlies light-grayish-red, moderate-reddish gray, and dark-red conglomerate, arkose, siltstone, shale, and dark-gray limestone of the Maroon Formation. West of Gibson Hill combined unit is about 180-m thick

PIPm, ls — **Maroon Formation (Late Pennsylvanian and Early Permian)**—Sequence of calcareous, coarse conglomerate, arkose, micaceous siltstone and shale, and limestone

Conglomerate—Light reddish gray, reddish tan, moderate reddish gray, dark red, and grayish purple. Conglomerate is dispersed-clast, polymict rock composed of well-rounded to subangular cobbles and pebbles in a matrix of granules and coarse-grained arkose. Channels are common. Normal, reverse, and central graded. Clasts composed of granite schist, gneiss, vein quartz, and large feldspar crystals. Primary bedding structures are planar and trough crossbeds, ripple cross-lamination, cuspate and linguoid ripple marks, and parting lineation. Secondary bedding structures are deformed crossbeds and load-casts

Sandstone—Light reddish gray, reddish tan, moderate reddish gray, moderate red, grayish red, dark red, and grayish purple. Channeled basal contacts. Normally graded. Planar and trough crossbeds, ripple cross-lamination, ripple marks, and parting lineation common primary bedding structures. Secondary bedding structures are deformed crossbeds and load casts

Siltstone, shale, and limestone—Dark reddish gray, dark grayish red, dark red, moderate red, and reddish tan. Siltstone is feldspathic and much siltstone is arkose. Shale and siltstone richly micaceous. Shale is rare. Most beds calcareous, argillaceous siltstone and argillaceous fine- and very-fine-grained sandstone. Primary bedding structures are ripple cross-lamination, cuspate and linguoid ripple marks, rill marks, and flute casts. Secondary sedimentary structures are small load casts and convolute bedding. Carbonate beds are moderate-gray and blackish-gray fossiliferous, fine-grained argillaceous and silty limestone. Nodular limestone is moderate gray and grayish-red, fine-grained limestone in shale and siltstone. Moderate-gray, dark-gray, and grayish-red limestone-pebble conglomerate, edgewise conglomerate, oolitic limestone occur locally. Lenticular limestone beds are as thin as 3 to 5 cm, but some limestone is 5 m thick

IPm — **Minturn Formation (Middle Pennsylvanian)**—Interbedded conglomerate, and green, black and gray, arkose, micaceous shale, micaceous siltstone, limestone, and dolomite. Calcite cement is common

Conglomerate—Light grayish pink, olive drab, grayish green, and greenish black. Framework-supported and matrix-supported clasts composed of rounded to subangular clasts of granite, gneiss, schist, quartzite, feldspar crystals, and vein quartz. Some beds contain isolated cobble-sized clasts in a pebble matrix. Prominent trough and planar crossbeds and channeled contacts. Carbonaceous matter occurs in some conglomerate beds

Sandstone—Light-grayish-tan, grayish-pink, light-gray, moderate gray, reddish-gray, grayish-red, and grayish-purple, micaceous, coarse-, medium-, and fine-grained arkose. Lenticular beds commonly 10-cm to 1-m thick. Composite sets about 12-m thick. Normal grading common. Primary bedding structures are planar and trough crossbeds, ripple cross-lamination, and shallow channels. Plant debris common

Siltstone and shale—Dark-gray, black, olive-drab, greenish-black, grayish-tan and occur in zones 2-cm to 4-m thick. Siltstones are arkose and many siltstone beds have a clay matrix. Shale beds contain silt- and sand-sized grains of quartz, feldspar, and rock fragments. Prominently micaceous. Shale is laminated and micro-laminated. Siltstone contains ripple cross-lamination. Micaceous black shale is prominent in lower part of Minturn Formation north of Hoosier Pass

Limestone and dolomite—Moderate-gray, dark-gray, and grayish-black, fine-grained, fossiliferous micritic beds that range from a few centimeters thick to 3 m thick. Locally mottled in moderate-gray and dark-gray colors. Commonly associated with black shale and dark-colored siltstone. Beds laterally discontinuous

Dc — **Chaffee Formation, undivided (Late Devonian)**—Shown only on cross section B–B'

Dcd — **Dyer Dolomite Member**—Laminated, light-yellowish gray, grayish-yellow, light-brownish-gray, mottled dolomite. Contains wavy microlamination. Very fine grained to fine grained and has conchoidal fracture

Dcp — **Parting Quartzite Member**—Grayish-red, gray, dark-reddish gray, grayish-orange, and black weathering, fine-, medium-, and coarse-grained, silica- or dolomite-cemented orthoquartzite and slightly feldspathic quartzite. Conglomerate at base. Planar crossbeds common in lower part. Beds are 3 to 30 cm thick

Om — **Manitou Limestone (Early Ordovician)**—Dark-, moderate-, and light-gray, thin- to thick-bedded dolomite cherty dolomite, and rare beds of dark-gray limestone. Grayish-pink and light-grayish-red dolomite beds occur in upper part. Upper 6 m contains casts of crinoids, shell fragments, and stromatolites. Sand grains and sandstone beds increase in upper part. Characteristic grayish-white chert nodules and rare black chert nodules are parallel to bedding planes

Ꞓsp — **Sawatch Quartzite and Peerless Shale, undivided (Late Cambrian)**—Shown only on cross section B–B'

Ꞓp — **Peerless Shale (Late Cambrian)**—Coarse-grained quartzite interbedded with black shale at base overlain by fine- and medium-grained quartzite, interbedded with dolomite-cemented sandstone and sandy and silty dolomite. Poorly exposed. Commonly represented in soil by clasts of rusty-weathering dolomite and dolomitic quartzite. Thins toward south

Ꞓs — **Sawatch Quartzite (Late Cambrian)**—Prominent basal conglomerate overlain by fine- and medium-grained quartzite. Conglomerate contains well-rounded quartz pebbles in a matrix of medium- and coarse-grained sand. Basal conglomerate is 18- to 32-cm thick, and contains planar crossbeds. Quartzite is medium-grained, well-sorted, subrounded, quartzite. Normally graded. Feldspar decreases upward. Lower part is grayish white and the upper part is reddish brown. Contains thin, laminated black shale interbeds. Unconformably overlies Middle Proterozoic metamorphic and igneous rocks

Yqm — **Biotite-muscovite quartz monzonite and granite (Middle Proterozoic)**—Light- to medium-gray and pinkish-tan, medium-grained, phaneritic-porphyritic quartz monzonite and granite. Euhedral, elongated, tabular phenocrysts of microcline feldspar as long as 2 cm (30 to 40 percent). Feldspar phenocrysts commonly display a crude alignment near pluton margins. Plagioclase crystals (25 to 35 percent) are smaller than microcline phenocrysts, and quartz (15 to 30 percent) is locally smokey quartz. Biotite is usually the dominant over muscovite (5 to 10 percent combined). Metamorphic foliation slightly developed. Irregular apophyses and dikes emanate from the stocks and plugs and grade into pegmatitic granite, pegmatite, and aplite

YXp — **Pegmatite, pegmatitic granite, and aplite, undivided (Middle and Early(?) Proterozoic)**—White to light-pink, discontinuous dikes and irregular masses of pegmatite, aplite and pegmatitic granite in the Tenmile Range. Most numerous in southern half of Tenmile Range. Consist primarily of quartz, microcline, plagioclase, muscovite, and biotite. Rarely, large (2 to 7 cm) masses of magnetite occur in pegmatite. Red-brown garnet a minor constituent locally. Pegmatites are commonly oriented east-west. Coarse pegmatitic zones grade into medium-grained pegmatitic granite and fine-grained aplite. Pegmatites and related bodies range from 2 to 25 m in width, averaging about 7 m

YXm — **Mafic dikes (Middle and Early Proterozoic)**—Narrow, mafic, fine-grained, lamprophyric dikes that discordantly intrude migmatitic gneiss and granodiorite. Dikes are typically massive to weakly foliated. Dikes are dark-gray to black, fine-grained to rarely aphanitic, and consist principally of hornblende and/or biotite, plagioclase, epidote (secondary), potassium feldspar (secondary), remnant pyroxene, chlorite (secondary), rounded, resorbed quartz grains (less than 10 percent), secondary(?) dolomite, magnetite and other opaque minerals (2 to 3 percent), and traces of apatite. Secondary potassium feldspar is present in the groundmass in some dikes. Locally, rounded masses of recrystallized phenocrysts give the rock a spotted appearance. Spots are fine-grained mineral aggregates

YXdi — **Diorite (Middle and Early(?) Proterozoic)**—Dark-gray, medium- to coarse-grained, massive to very weakly-foliated diorite occurring as small plutons in the northern half of the quadrangle. The diorite consists principally of plagioclase (40 to 60 percent), hornblende (30 to 55 percent), biotite (5 to 10 percent), and quartz (5 to 10 percent). Opaque minerals (mostly magnetite) constitute 2 to 4 percent. Pyroxene is present only in small amounts. Chlorite and epidote are common alteration products. Accessory apatite and sphene. Age not known

Xgg — **Granitic gneiss (Early Proterozoic)**—Light-gray, light-pink-gray, to pink-green, medium- to coarse-grained, and moderately foliated to locally well-foliated. It consists principally of 50 to 65 percent feldspar (mostly pink to white potassium feldspar, lesser plagioclase), 25 to 35 percent quartz, and 10 to 15 percent biotite, which is usually partially or completely altered to chlorite. Biotite aggregates commonly form clots and lenses. Small amounts of muscovite and opaque minerals are also present. Kellogg and others (2002) noted garnet, zircon, and apatite as accessory minerals. Thin (0.2 to 2 cm) shear planes composed mostly of chloritized biotite are common, and give rock a streaky appearance in places

Xg — **Alaskitic granite (Early Proterozoic)**—Irregularly-shaped intrusions are white to very light-gray to light-tan, fine- to medium-grained and generally xenomorphic. The rock sometimes appears aplitic. Composed of microcline and orthoclase (50 to 60 percent), quartz (30 to 40 percent), muscovite (5 to 10 percent), and minor plagioclase. Bergendahl (1963) noted fine-grained magnetite, pyrite, chlorite, and biotite as very minor constituents. Displays weak but consistent metamorphic (?) foliation. Largest body located on the northern side of Peak 10

Xgd — **Granodiorite gneiss (Early Proterozoic)**—Medium- to dark-gray, medium- to coarse-grained, porphyritic, well-foliated granodiorite gneiss. Locally grades into quartz monzonite gneiss or quartz monzodiorite gneiss based on mineral content. Contains 15 to 35 percent biotite, 15 to 40 percent quartz, and 30 to 60 percent feldspar (mostly plagioclase). Only minor amounts of hornblende and pyroxene. Accessory minerals include apatite, sphene, and rutile. Forms small- to medium-sized plutons, the largest being in the southern part of the map area. Granodiorite is usually well-foliated and foliation is parallel to the regional foliation of the migmatitic gneiss. Feldspar phenocrysts (porphyroblasts?) are locally as long as 4 cm, especially near the margins of plutons

Xmg — **Migmatitic biotite gneiss (Early Proterozoic)**—Medium- to dark-gray, dark-brownish-gray, and locally dark-reddish-gray or rusty-brown, well-foliated, medium-grained, migmatitic biotite gneiss. Light-colored (felsic) pegmatitic to granitic layers and irregular veins consisting mostly of quartz and feldspar are interlayered with darker biotite-rich layers. Felsic layers are coarse-grained and range from 0.5 cm to 20 cm thick and commonly show ptygmatic folds and boudinage structures. Felsic layers constitute from 20 to 70 percent of the gneiss (Kellogg and others, 2000). Dark layers consist primarily of quartz, plagioclase, biotite, and microcline in varying proportions. Sillimanite occurs at a few places where it is light-gray or colorless fibrous to bladed clots and masses in layers. Garnet, where present, occurs as fractured porphyroblastic crystals (Bergendahl, 1963). A few thin, discontinuous layers (<2 m) of meta-quartzite occur in the migmatitic biotite gneiss near Peak 10 and Crystal Peak

Xb — **Biotite gneiss (Early Proterozoic)**—Medium-gray, medium-grained, well-foliated biotite gneiss that consists of quartz (30 to 50 percent), plagioclase (20 to 30 percent), and biotite (10 to 15 percent). Accessory minerals are microcline, muscovite, hornblende, and sillimanite (Kellogg and others, 2000). Lithologically and mineralogically similar to migmatitic biotite gneiss, but lacks the high percentage of felsic layers, ptygmatic folds and boudinage of migmatitic biotite gneiss. Contains only 5 to 20 percent felsic layers. Biotite gneiss has more parallel layering and is typically less folded at outcrop scale than migmatitic biotite gneiss

Xf — **Felsic gneiss (Early Proterozoic)**—Mapped only in one poorly exposed area in the northern part of the map area. Fine- to medium-grained, light-tan to light-gray, moderately well-foliated gneiss. Consists dominantly of quartz and feldspar. Thin, green, chloritic layers are common. These appear to be derived from the alteration of biotite-rich layers

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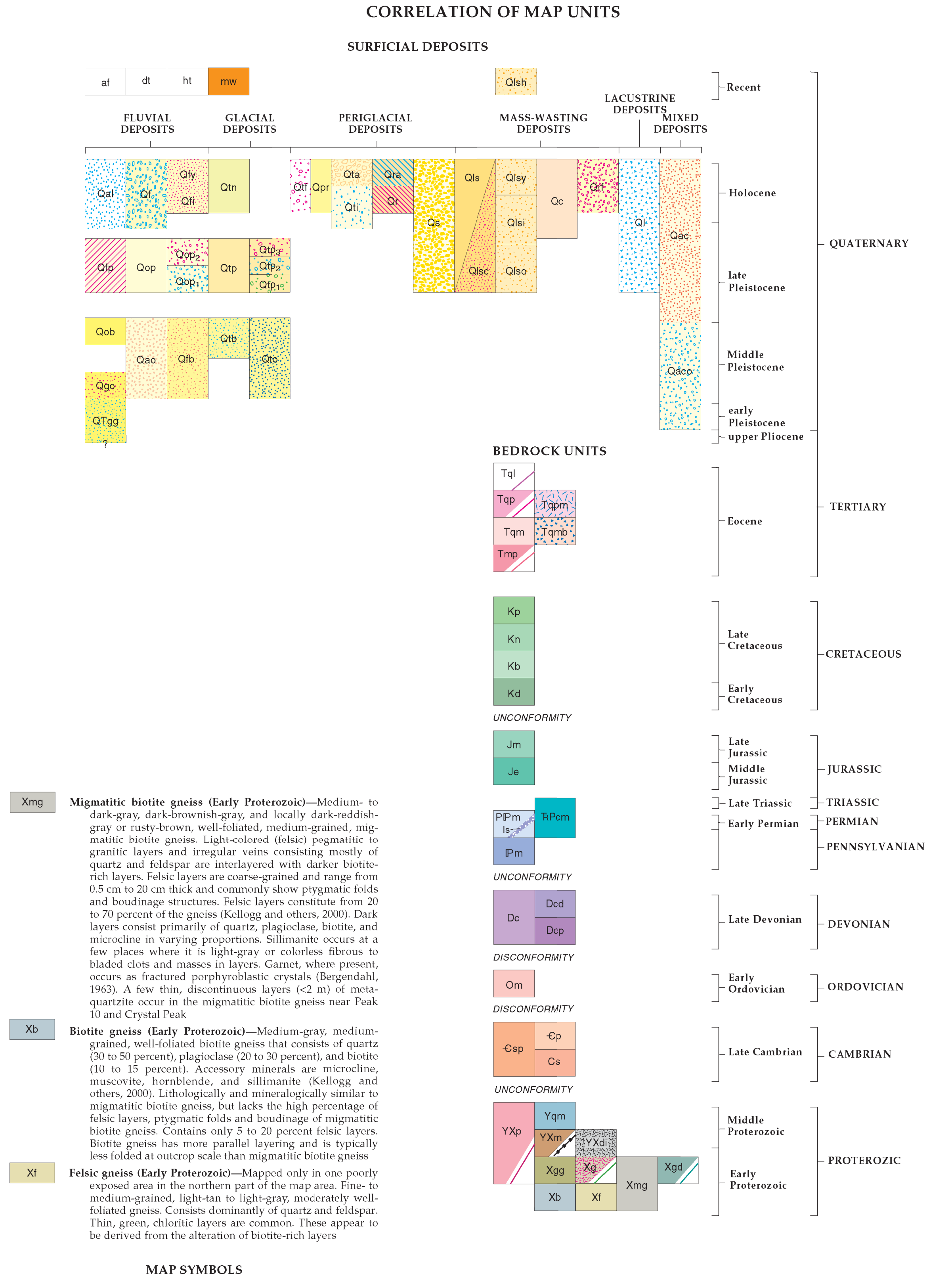
CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact—Dashed where approximate

Normal Fault—Dashed where approximately located and dotted where covered by younger deposits. Ball and bar on downthrown block; arrow and number show dip of fault plane; [half arrows show relative slip of fault plane (cross section only)]

Shear zone—Relative direction and amount of slip not known

Anticline—Trace of axial surface. Dashed where approximately located and dotted where covered by younger deposits. Large arrowhead shows direction of plunge and small arrows show direction of dip away from the axial trace

Syncline—Trace of axial surface. Dashed where approximately located and dotted where covered by younger deposits. Large arrowhead shows direction of plunge and small arrows show direction of dip toward the axial trace

Strike and dips of beds
Inclined
Inclined (red) from Taranik (1974)

Strike and dip of foliation in metamorphic rocks
Inclined
Vertical

Strike and dip of joint or fracture set

Sackung

Landslide headscarp

Moraine ridge

Direction of slip in landslide deposit

010159 — **Location of $^{40}Ar/^{39}Ar$ age date sample**

K01-129 — **Location of rock geochemical sample**

A——A′ — **Line of section**

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State of Colorado
Greg E. Walcher, Executive Director,
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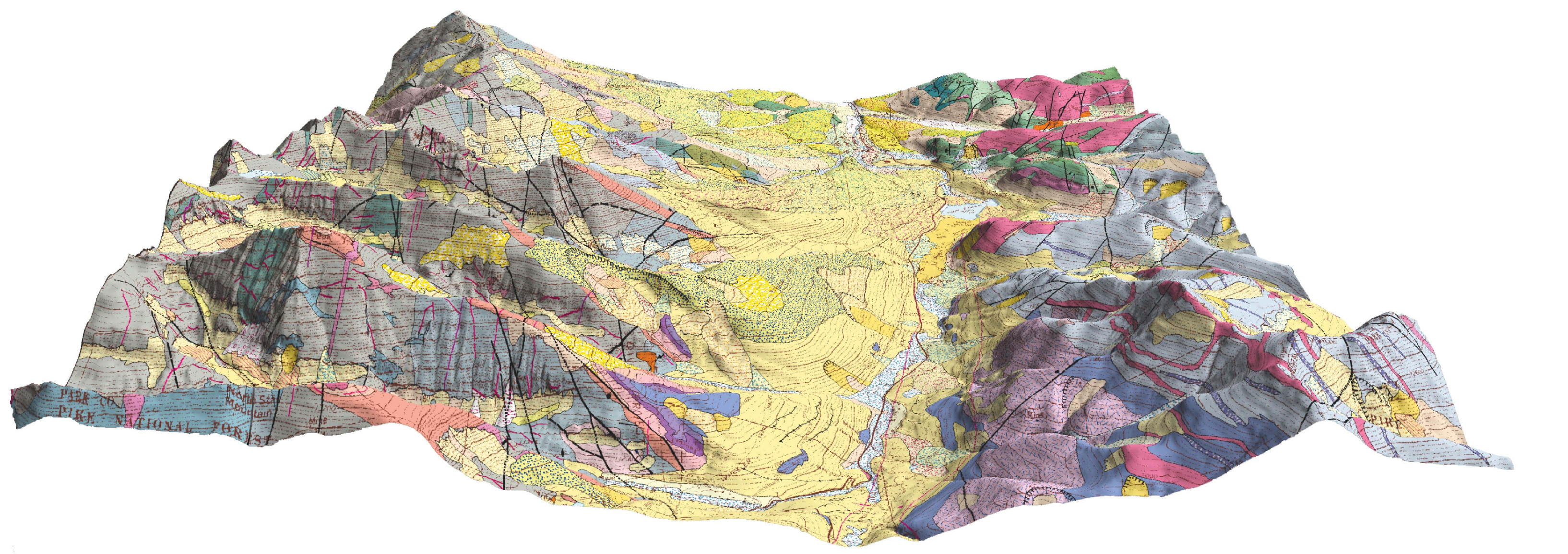
COLORADO GEOLOGICAL SURVEY

SHADED-RELIEF MAP OF THE BRECKENRIDGE QUADRANGLE WITH GEOLOGY AND TOPOGRAPHY OVERLAY, OBLIQUE VIEW LOOKING NORTH



GEOLOGIC MAP OF THE BRECKENRIDGE QUADRANGLE, SUMMIT AND PARK COUNTIES, COLORADO

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2003