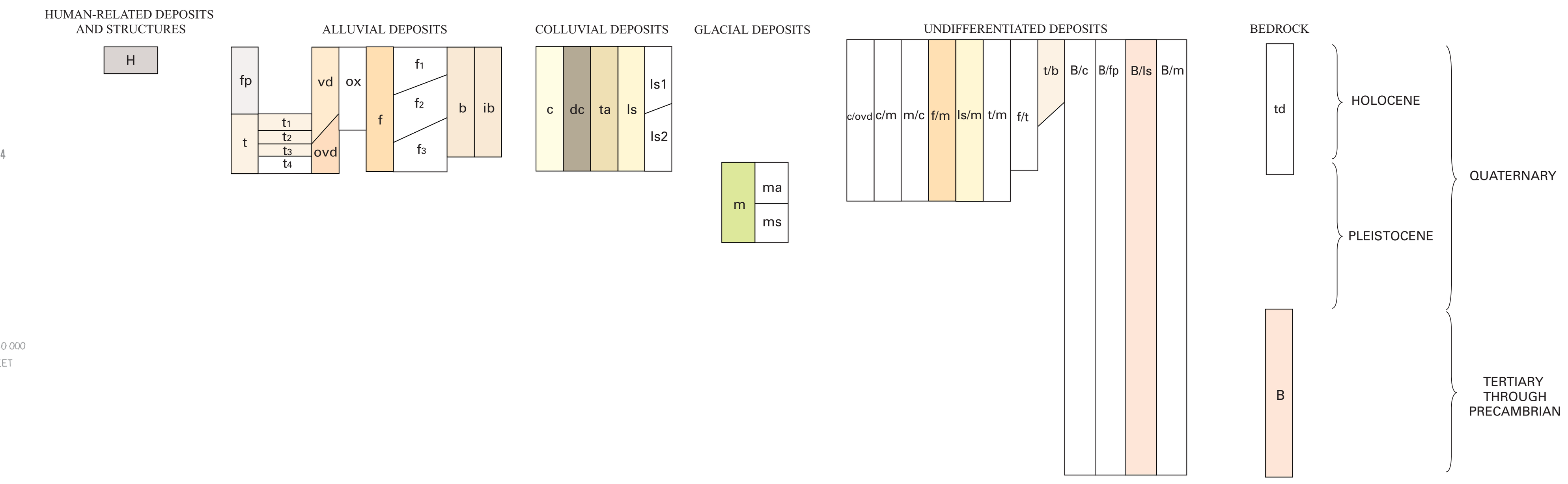
Base from U.S. Geological Survey, 1955; photorevised 1978
Projection: Universal Transverse Mercator, zone 13.
10,000-foot grid based on Colorado coordinate system, south zone.
1927 North American datum

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped by Blair, 1998–1999.
Digitally compiled by Yager, 1998–1999.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Unit descriptions do not differ between plates 1 through 10 with the exception of bedrock, which does differ based on lithologies and geologic formations represented in a mapped area. Prefix "r" indicates alluvial, colluvial, or glacial deposits disturbed by human activities. For example, rfp refers to reworked floodplain deposits from gravel mining operations. Unit symbols separated by a slash indicate that two units are preserved in mapped area; color in box denotes predominant unit. Uncolored boxes denote units not mapped on this plate]

HUMAN-RELATED DEPOSITS AND STRUCTURES

H — **Human works (upper Holocene)**—Includes human-caused deposits and structures larger than 10 m in length, such as fluvial mine tailings, ramps, buildings, open pits, and mine waste piles. Structures are either intact or in a state of decay and consist of wooden planks, stone or concrete pads with iron, steel, or aluminum sheets, beams, rebar, wire, and a variety of discarded machinery. Fluvial mine tailings are well sorted and consist of fine-grained sand, silt, and clay-size sediment. Mine waste piles consist of poorly sorted, sand-to boulder-size fragments with a silt matrix; minerals such as pyrite, galena, sphalerite, hematite, jarosite, and goetite are common. The sulfide and oxide minerals impart yellow, orange, and reddish color to these dumps. Human works were constructed between 1870 and the present. Natural processes such as snow avalanches, local flooding, and slope failure aided in the modification and destruction of historic human works. Some human works such as adits and mine dumps are point sources for acidic waters, which discharge elements such as Al, Fe, Cu, Zn, As, and Pb to streams

ALLUVIAL DEPOSITS

fp — **Floodplain deposits (upper Holocene)**—Unconsolidated sand and gravel, commonly with silt matrix; poorly sorted, subround to round gravels, commonly imbricated; boulders as much as 0.5 m in diameter common in upper Animas River watershed. Deposited in active stream channels and as overbank sediment on adjacent terraces less than 1 m above channel. Mostly deposited during spring floods and storm discharge events. Natural, fluvial processes throughout the watershed and, in places, human activities, such as between Eureka and Howardsville, have reworked many floodplain deposits since 1860. Red (iron oxide), white (aluminum hydroxide), and black (manganese oxide) staining of floodplain sediments in some reaches indicates high concentrations of dissolved metals. Thickness 1–10 m

t (t_1, t_2, t_3, t_4) — **Terrace deposits (Holocene to uppermost Pleistocene)**—Unconsolidated sand and gravel with silt matrix; poorly sorted, subround to round gravels, commonly imbricated; boulders as much as 0.5 m in diameter common in upper watershed reaches. In highly mineralized drainages, iron-oxide cements form ferricrete (iron-cemented conglomerate). Sediment is deposited during spring runoff and storm over-bank flow discharge events. Surfaces are narrow and flat, and parallel the modern stream channel. Where differentiated by their relative ages, youngest terraces are labeled t1, lie 1–2 m above the modern channel, and predate 1860 (Kirk Vincent, U.S. Geological Survey, written commun., 2001). Sequentially higher and older terraces are designated t2, t3, and t4. Higher terraces display stronger color and textural B soil horizons. Terrace height above the stream channel varies from 2 to 10 m. Terraces in the headwater regions of the Animas River watershed are not necessarily correlative with terraces in the lower Animas River basin. Thickness 1–10 m

vd — **Valley deposits (upper Holocene)**—Unconsolidated sand and gravel with a silty matrix and occasionally larger stones derived from valley sides. Deposits formed by fluvial and colluvial processes including periodic floods, small debris flows, and slope wash. Deposits often found on slightly concave valley floors near the heads of tributaries where no distinct fluvial terraces or alluvial fans can be found. Deposits are both historic and pre-historic in age. Thickness 1–5 m

ovd — **Old valley deposits (Holocene to uppermost Pleistocene)**—Unconsolidated sand and gravel with a silty matrix and occasionally larger stones derived from valley sides. Deposits formed by fluvial and colluvial processes including periodic floods, small debris flows, and slope wash. Same as valley deposits (vd) in mode of formation except unit ovd occupies older concave surfaces now perched above the modern valley floor. Thickness 1–5 m

f (f_1, f_2, f_3) — **Alluvial fan deposits (Holocene to uppermost Pleistocene)**—Unconsolidated, poorly sorted sand and gravel with silt matrix; cobbles and boulders common. Sediment supplied episodically to fan surfaces by streams and debris flows along confined, commonly braided channels from seasonal storm runoff events. Form as fan-shaped deposits (in map view) at mouths of streams where stream gradient and velocity decreases and where topography widens from confined channels to open valleys. Surface gradients are less than 20°. Fan development post-dates glaciation and therefore their growth was initiated after 15 ka. Where the relative fan age can be differentiated from cross-cutting geometry, the younger fan segments are designated as f1 and the older as f2 and f3. Thickness 1–20 m

b — **Bog deposits (Holocene)**—Consist of water-saturated, spongy masses of live and decayed vegetation, bacteria, and peat often associated with shallow standing water. Masses of organic matter produce strong reducing and often, anoxic depositional environments. Forms wetland surfaces, often hummocky and stair stepped on gentle hill slopes adjacent to streams or active springs. Commonly found behind beaver dams. Ages range from present to thousands of years (Stan Church, written commun., 2001). Thickness 1–5 m

ib — **Iron bog deposits (Holocene)**—Similar to bog deposits (b), but with high concentrations of iron oxides and other metal oxides that are associated with thiobacilli and other metal-loving bacteria (Spratt and others, 1999). Presence of metals indicates that deposits can act as cation sinks and, when metal saturated, mark the source of acidic waters and waters with low dissolved oxygen content (Stan Church, written commun., 2001). Thickness 1–5 m

COLLUVIAL DEPOSITS

c — **Colluvial deposits (upper Holocene to uppermost Pleistocene)**—Unconsolidated soil and sand- to cobble-size debris derived from valley walls. Processes include rockfall, sheetwash, and creep. Colluvium is discontinuous on the valley sides and produces irregular-shaped, hummocky surfaces. Growth has been continuous since glacial retreat. Thickness 1–5 m

dc — **Debris cone deposits (Holocene to uppermost Pleistocene)**—Unconsolidated, poorly sorted silt, sand, and gravel with angular cobbles and boulders derived from source gullies. Fluvial and colluvial processes predominate. Deposit volume increases through time due to freeze-thaw weathering processes. Seasonal thunderstorm events result in rock falls, debris flows, and sheet wash onto the cone. Debris cones are fan shaped in map view, have slopes greater than 20°, and are found at the mouth of steep bedrock gullies. Growth has been continuous since glacial retreat. Thickness 1–10 m

ta — **Talus deposits (upper Holocene to uppermost Pleistocene)**—Unconsolidated, poorly sorted, angular, cobble-size stones and blocks derived from rock falls above the talus field. Deposits blanket topography on steep valley slopes at the angle of repose (33°–35°). Growth has been continuous since glacial retreat. Thickness 1–5 m

ls — **Landslide deposits (upper Holocene to uppermost Pleistocene)**—Unconsolidated, poorly sorted silt to angular boulder-size clasts consisting of lithologies derived from local formations. Includes deposits formed mainly by translational and rotational slope failure stemming from over steepening by fluvial and glacial erosion and weathering. Deposits form lobate, hummocky surfaces along valley sides. In glacial valleys, the larger landslides formed as glacial ice withdrew. Ages of most deposits unknown. Where relative age of adjacent landslide deposits can be differentiated from cross cutting geometry, the younger segments are designated as ls1 and the older as ls2. Thickness 1–10 m

GLACIAL DEPOSITS

m (ma, ms) — **Glacial till deposits (upper Pleistocene)**—Unconsolidated to compacted poorly sorted, clay- to boulder-size sediment derived from ablation of glaciers at ice margins. Form hummocky end and lateral moraine ridges. Best displayed at north end of Durango and near Silverton. Deposits represent the last vestiges of glaciers between 12 and 15 ka. Carrara and others (1984) and Maher (1972) indicated ice-free conditions existed as early as 15 ka, but recent data indicate ice-free conditions at around 12 ka (Gillam, 1998). Till deposits north of Durango are subdivided into two relative ages. Animas City moraines (ma) are 12–35 ka and Spring Creek moraines (ms) are 85–160 ka (Gillam, 1998; Carroll and others, 1999). Thickness 1–20 m

UNDIFFERENTIATED DEPOSITS

f/m — **Fan and glacial till deposits (Holocene to upper Pleistocene)**—See descriptions for fan (f) and glacial till deposits (m)

ls/m — **Landslide and glacial till deposits (Holocene to upper Pleistocene)**—See descriptions for landslide (ls) and glacial till deposits (m)

t/b — **Terrace and bog deposits (Holocene to uppermost Pleistocene)**—See descriptions for terrace (t) and bog deposits (b)

B/ls — **Bedrock and landslide deposits (Holocene to Precambrian)**—See descriptions for bedrock (B) and landslide deposits (ls)

BEDROCK

B — **Bedrock (Tertiary to Precambrian)**—Bedrock forms the exposed valley walls and occasional knobs on the valley floor with thin to no soil cover. Where soil cover is thin, vegetation cover may be present. Bedrock consists of Tertiary intermediate composition, lava flows, volcaniclastic sedimentary rocks, mudflow deposits, granitic intrusions, Paleozoic limestone, and Precambrian gneiss and schist below Silverton in the upper Animas Canyon. Ages of igneous and volcaniclastic rocks range from 35 to 27 Ma (Steven and others, 1974; Yager and Bove, 2002)

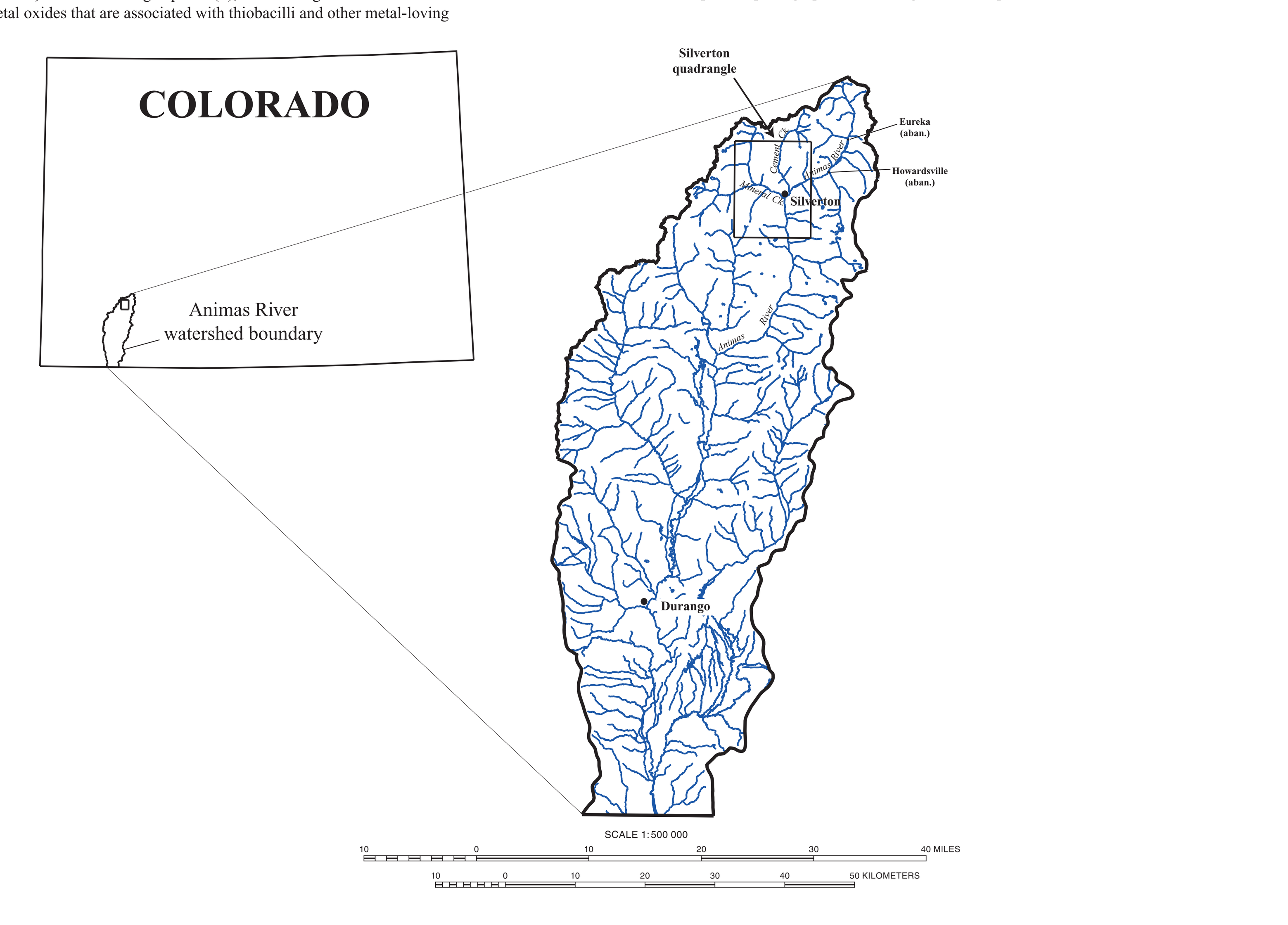
Contact—Dashed lines are contacts between geomorphic features in a map unit

w — **Water**

35 — **Site of photograph**—Camera symbol is located where photograph was taken and camera symbol lens is approximately oriented in direction of photograph. Click on each photograph icon to view a linked .pdf-file photograph and site description

II — **Geochemical profile**—Mineral Creek terrace, circa 1750–1800 A.D. Click on roman numeral to view a linked .pdf-file photograph and related geochemical profile

III — **Geochemical profile**—Cement Creek, pre-mining terrace. Click on roman numeral to view a linked .pdf-file photograph and related geochemical profile



SURFICIAL GEOLOGY ALONG THE MIDDLE AND SOUTH FORKS OF MINERAL CREEK, MINERAL AND CEMENT CREEKS, AND THE ANIMAS RIVER IN THE SILVERTON QUADRANGLE, ANIMAS RIVER WATERSHED, SAN JUAN COUNTY, COLORADO

By
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2002